A DISSERTATION
ON

CLIMATE CHANGE AND AGRICULTURE IN INDIA: IMPLICATIONS FOR RURAL POOR

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Certificate

This is to certify that the dissertation entitled ***"Climate Change and Agriculture in India: Implications for Rural Poor"****, submitted by Ms* ***Juhi Shamim*** *has been completed under my supervision. To the best of my knowledge this dissertation is the original work of research and is suitable for submission for the award of MPhil. Degree in Economics.*

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ABBREVIATION

ADB	-	Asian Development Bank
BBC	-	British Broadcasting Corporation
BCM	-	Billion Cubic Meters
CAIT	-	Climate Analysis Indicators Toolkit
CAP	-	Common Agricultural Policy
CWC	-	Central Water Commission
DAC	-	Department of Agriculture and Cooperation
DES	-	Directorate of Economics and Statistics
EUC	-	European Commission
FAO	-	Food and Agriculture Organization
FMOs	-	Flood Metrological Offices
GDP	-	Gross Domestic Product
GHG	-	Green House Gases
GLOFs	-	Glacial Lake Outburst Floods
IARI	-	Indian Agriculture Research Institute
IMD	-	India Metrological Department
IPCC	-	Intergovernmental Panel on Climate Change
LAP	-	Long Period Average
MDGs	-	Millennium Development Goals

Mha	-	Million Hectares
NATCOM	-	National Commission
NCIWRD	-	National Commission on Integrated Water Resource Development
NDDB	-	National Diary Development Board
NGOs	-	Non-Governmental Organizations
NLP	-	National livestock Policy
NSS	-	National Survey Scheme
ODI	-	Overseas Development Institute
OECD	-	Organization for Economic Cooperation and Development
OF	-	Operation Flood
RBA	-	Rashtriya Barh Ayog
SPI	-	Subsequent Protocol Identifier
UK	-	United Kingdom
UN	-	United Nation
UNDP	-	United Nations Development Programme
UNFCCC	-	United Nations Framework Convention on Climate Change

UNICEF	-	United Nation's International Children's Emergency Fund
WB	-	World Bank
WDR	-	World Development Report
WFC	-	World Fish Centre
WMO	-	World Meteorological Organization
WRI	-	World Resources Institute
WTO	-	World Trade Organization
WWC	-	World Water Council

Chapter-1
Introduction

INTRODUCTION

1.1 Introduction

Among all sectors of the economy agriculture is termed as most sensitive to the climate. The productivity and thus the production of agricultural commodities are primarily determined by the climatic conditions in ceteris paribus condition because it not only helps in the growth of the crops and their health but also decides the quality and texture of the soil which is the primary determinant. A change in climate is expected to bring changes in almost all the spheres of agricultural practices.

The agriculture sector plays a crucial role in the country's development. Food grain production quadrupled during the post-independence era; hence this growth is projected to continue. The impact of climate change on agriculture could result in problems of food security and may threaten the livelihood activities upon which much of the population depends. Climate change can affect crop yields (both positively and negatively) as well as the types of crops that can be grown in certain areas by impacting agricultural inputs such as water for irrigation, amounts of solar radiation that affect plant growth, as well as the prevalence of pests. The Indian Agricultural Research Institute (IARI) examined the vulnerability of agricultural production to climate change with the objective of determining differences in climate change impacts on agriculture by region and by crop.

At the same time agriculture has been shown to produce significant effects on climate change, primarily through the production and release of greenhouse gases such as carbon dioxide, methane and nitrous oxide but also by altering the Earth's land cover which can change its ability to absorb or reflect heat and light and thus contributing to radioactive forcing. Land use change such as deforestation and desertification together with use of fossil fuels are the major anthropogenic sources of carbon dioxide. Agriculture itself is the major contributor to increasing methane and nitrous oxide concentrations in earth's atmosphere (UN Report, 2007).

While climate change affects everyone, it is the world's poor who are on the front line. Although agriculture contribute only 14 percent of India's GDP (Economic Survey, 2012-13), its importance in the country's economic, social, and political fabric goes well beyond this indicator. Rural areas are still home to some 68.84 percent of India's 1.1 billion people (Census, 2011), most of who are poor and marginalized and rely on agriculture as their main source of income (World Bank 2009).

Researchers at the Overseas Development Institute (ODI) have investigated the potential impacts climate change could have on agriculture, and how this would affect attempts at alleviating poverty in the developing world (Rachel, S.; Paskett, L.; Eva, L. and David, B.; 2007). They argued that the effects from moderate climate change are likely to be mixed for developing countries. However, the vulnerability of the poor in developing countries to short term impacts from climate change, notably the increased frequency and severity of adverse weather events is likely to have a negative impact. This should be taken into account while defining agricultural policy. (Rachel, S.; Paskett, L.; Eva, L. and David, B.; 2007).

Smaller farms are dependent on timely and sufficient rainfall during the monsoon for high crop yields. However with the changing climate, rainfall patterns have become erratic and reduced leaving farmers exposed to many risks including droughts, floods, disease of both crops and animals and unpredictable market irregularities (Venkateswarlu, 2009). Indeed it is estimated that every 1°C increase in temperature is likely to lead to a 5-10 percent reduction in yields of some crops (Pachauri, 2009).

Climate change will lead to increase hardship for India's poorest women. Women in India, especially in rural areas, are often responsible for providing daily essentials such as food and water. With respect to disaster strike, climate change research has shown that the workload of women and girls increases, thus leading to their exclusion from opportunities like education and a diminishment in their equal participation in development. For example, deforestation increases the time women need to spend looking for fuel. Research has further shown that women have fewer means to adapt and prepare for extreme weather conditions.

Many poor women are also actively engaged in agricultural activities, including paddy cultivation and fishing that will be affected by changing weather patterns in India. Loss of livelihood will increase their vulnerability and marginalization (UNDP 2007/08).

1.1.1 Impact of Climate Change on Agriculture

Despite technological advances, such as improved varieties, genetically modified seeds and irrigation systems, weather is still a key factor in agricultural productivity as well as soil properties and natural communities. The effect of climate on agriculture is related to variability in local climates rather than in global climate patterns. Consequently, agronomists consider that any assessment has to be individually considered in each local area. Most agronomists believe that agricultural production will be mostly affected by the severity and pace of climate change, not so much by gradual trends in climate. If change is gradual, there may be enough time for biota adjustment. Rapid climate change, however, could harm agriculture in many countries, especially those that are already suffering from rather poor soil and climate conditions, because there is less time for optimum natural selection and adoption. Different studies have found the impact of climate change on agriculture differently.

Although increase in carbon dioxide is likely to be beneficial for several crops, associated increase in temperatures, and increased variability of rainfall would considerably impact food production. Recent IPCC report and a few other global studies indicate a probability of 10 – 40 percent loss in crop production in India with increases in temperature by 2080 – 2100 (IPCC, 2007).

There are a few Indian studies on this theme and they generally confirm similar trend of agricultural decline with climate change. Recent studies done at the Indian Agricultural Research Institute indicate the possibility of loss of 4-5 million tonnes in wheat production in future with every rise of 1°C temperature throughout the growing period (but no adaptation benefits). It also assumes that irrigation would remain available in future at today's levels. Losses for other crops are still uncertain but they are expected to be relatively smaller, especially for kharif crops (IARI, 2007).

It is, however, possible for farmers and other stakeholders to adapt to a limited extent and reduce the losses. Simple adaptations such as change in planting dates and crop varieties could help in reducing the negative impacts of climate change to some extent. For example, the Indian Agricultural Research Institute study quoted above indicates that losses in wheat production in future can be reduced from 4-5 million tonnes to 1-2 million tonnes if a large percentage of farmers could change to timely and changed to better adapted varieties. This change of planting would, however, need to be examined from a cropping systems perspective (IARI, 2007).

Increasing climatic variability associated with global warming will, nevertheless, result in considerable seasonal/annual fluctuations in food production. All agricultural commodities even today are sensitive to such variability. Droughts, floods, tropical cyclones, heavy precipitation events and heat waves are known to negatively impact agricultural production and farmers' livelihood. The projected increase in these events will result in greater instability in food production and threaten livelihood security of farmers (Sudarkodi, K.; Sathyabama, K., 2011).

Increasing glacier melt in Himalayas will affect availability of irrigation especially in the Indo-Gangetic plains, which, in turn, has large consequences on our food production (Sharma, A., 2008).

Global warming in short-term is likely to favour agricultural production in temperate regions (largely northern Europe, North America) and negatively impact tropical crop production (South Asia, Africa). This is likely to have consequences on international food prices and trade and hence our food security (Dev, M. S., 2011).

Small changes in temperature and rainfall could have significant effect on quality of cereals, fruits, aromatic, and medicinal plants with resultant implications on their prices and trade (DES, DAC, 2010).

Pathogens and insect populations are strongly dependent upon temperature and humidity. Increases in these parameters will change their population dynamics resulting in yield loss (Corroson, P., 2004)

1.2 Review of Literature

The review of existing literature related to a research problem is the most important part of the academic research. It not only gives an insight into the nature and dimension of the problem but also gives the information about the relationship among the various parameters and their degree of association. The importance of available literature also increases because it provides a detail account of the earlier studies and help in finding the gap that exist in the literature which became a base and gives direction for the new researchers. In this section a modest attempt has been made to give a brief account of literature related to the climate change and agriculture.

This paper, **"The Impact of Climate Change on Agriculture"** by **Sudarkodi, K. and Sathyabana, K. (2011),** provides an insight into the different climate change related challenges that the agricultural sector will face and explores opportunities for emission reduction and adaptation. This paper clearly indicates that the sector deserves more attention when it comes to both climate change threats and opportunities. The result shows that climate change is likely to have a significant negative impact on agricultural production, prompting output reduction that will greatly affect parts of the developing world. They concluded that climate change, adaptation and mitigation have to proceed simultaneously. Effective adaptation therefore, requires a judicious selection of measures within a policy context and a strategic development framework, but must also explicitly counter the impact of climate change, particularly with respect to the poor.

The Paper, **"Climate Change, Rural livelihoods and Agriculture (Focus on Food Security) in Asia – Pacific region"** is presented by **S. Mahendra Dev (2011).** The objective of this paper is to identify climate change related threats and vulnerabilities associated with agriculture as a sector and agriculture as people's livelihoods (exposure, sensitivity, adaptive capacity). This paper analyses the connections between the nature of human actions as drivers of threats as well as opportunities for sustainable agriculture and better human development outcomes. Broadly, it examines the impact of climate change on rural livelihoods, agriculture and food security. He concluded that rural households get livelihoods through agriculture, rural non-farm sector and migration. Also the sources of livelihoods differ from one country to another. Further he concluded that the impact of observe changes in climate trends, variability and extreme events show that the crop yield in many countries of Asia has declined, partly due to rising temperatures and extreme weather events.

Amrit Patel (2011) in his paper, **"Climate Change and Agriculture in India: Need for Mitigation and Adaptation"** discusses so far as India is concerned, climate change is likely to affect agriculture adversely and increase the risk of hungers and drinking water scarcity due to enhanced variability and more rapid melting of glaciers. He concluded that agriculture development in India needs to focus on reducing greenhouse gas emission through various measures, such as significant reduction of deforestation, improving forest conservation and management, effective control of wildfires, promotion of agro-forestry for food or energy, soil carbon sequestration, restoring land through controlled grazing, improving nutrition for ruminant livestock, efficient management of livestock waste, and developing strategies that conserve soil and water resources by improving their quality, availability and efficiency of use.

Singh Mahesh Kumar (2010), in his Ph.D dissertation on **"Socio-Economics of Climate Change: Impact on Agriculture Land Use Changes in India"** determines, how the different major socio-economic indicators are varying according to climate change in India and also find out the vulnerability index to determine the impact assessment. At the same time, he investigated comparative variations in production, yield, growth rates and other agricultural dimensions. By measuring the agricultural land use changes and effect of climate change he provided detail idea about how the socio-economic of climate change phenomenon affect the agriculture land use change in India.

Shakeel, A. Khan; S. Kumar,; M.Z. Hussain and N. Kalra (2009), in their study, **"Climate Change, Climate Variability and Indian Agriculture: Impacts, Vulnerability and Adaptation Strategies",** stated that, the impact of climate change and vulnerability on agriculture is a high priority in India as the impact, if it follows the predictions, is expected to be widespread and severe. Developing the ability to confidently estimate the impacts of climate change on agriculture is critically important. If ever achieved, it could provide the global information needed to help farmers develop their own long range response to climate change. They concluded that the accuracy in assessing the magnitude of the climate change on higher spatial and temporal resolution is the prime requirement for accurate estimates of the impact. Socio-economic aspects of climate change are relatively weak and future scenarios are to be generated for various agro-ecological regions for subsequently linking with other relational layer to work out the impact.

"Climate Change: Perspectives from India" is a collection of articles by **Sunita Narain, Jyoti Parikh, Prodipto Ghosh, N.C. Saxena and Preeti Soni (2009)**. This collection of articles captures and disseminates some perspectives on climate change from the Indian perspective. Starting from an argument on a new climate deal to highlight the importance of the small scale industrial sector within climate change debates, some of India's best known environmentalists, economists and policy makers have put forward their concerns and convictions in this collection. Sunita Narain argues that, "there is not much difference between managing a local forest and the global climate. Both are common property resources. What is needed most of all is a property rights framework, which encourages cooperation". Prodipto Ghosh analysis brings out that a country can have both growth and less carbon emission. N.C. Saxena strongly advocates adaptation to climate change through soil and water conservation. Jyoti Parikh has identified the special vulnerabilities of women to climate change. Preeti Soni has brought into focus an important but ignored sector: the small scale industries. She has identified ways in which this sector can be made energy efficient.

Ashwani Sharma (2008), in her paper, **"Impact of Climate Change on Indian Agriculture"** discusses the effects of Green-House Gases (GHG) which results in global warming. She finds out that the increasing GHG resulted in global warming by 0.74°C over past 100 years and 11 of the 12 warmest years were recorded during 1995-2006. According to her, some changes will affect agriculture through their direct and indirect effects on crops, soils, livestocks, fisheries and pests. Tropical countries are likely to be affected more compared the countries situated in temperate regions.

The study on **"Adaptation to Climate Change in the Agricultural Sector" (2007),** aims to provide the European Commission (EUC) an improved understanding of the potential implications of climate change and adaptation options for European agriculture, covering the EU 27 Member States. It also aims to assist policy makers as they take up the adaptation challenge and develop measures to reduce the vulnerability of the sector to climate change. The study comprised a series of tasks representing a logical progression from an assessment of climate change impacts, through an analysis of risks and opportunities, and identification of adaptation options, to potential integration into the Common Agricultural Policy (CAP). It concluded that the measures to adapt crop and livestock production need to be given greater attention. Simultaneously, there is a need for EU members to help farmers cope with the forecasted loss of agricultural production in Southern Regions.

John F. Morton (2007) in his paper, **"The Impact of Climate Change on Smallholder and Subsistence Agriculture"**, proposed a conceptual framework for understanding the diverse forms of impacts in an integrated manner and identified the future research needs. He concluded that smallholder and subsistence farmers will suffer impacts of climate change that will be locally specific and hard to predict. Social scientific study of the future impacts of climate change on poor rural people in developing countries has tended to be concerned with the increased frequency of extreme events with generalized impacts.

R.P.S. Malik (2006), in his paper, **"Indian Agriculture; Recent Performance and Prospects in the Wake of Globalization"**, attempts to present a brief review of the recent growth performance of Indian agriculture and some of the agricultural support policies that have a major impact on agriculture. The paper provides a brief description of the status of WTO negotiation in agriculture and the Indian stand on some of these issues under negotiations. In the light of this discussion, the paper then gives a brief review of some of the recently conducted studies on the potential impacts of these negotiations on agricultural prices, trade, production and welfare.

The Paper, **"Implications of Climate Change for agricultural productivity in the early twenty first century"** is presented by **J. Gornall, R. Betts, E Burke, R. Clark, J. Camp, K. Willett and A. Wiltshire.** This paper reviews recent literature concerning a wide range of processes through which climate change could potentially impact global-scale agricultural productivity and presents projections of change in relevant meteorological, hydrological and plant physiological quantities from a climate model ensemble to illustrate key areas of uncertainty. Its aim is to provide a global-scale overview of all relevant impacts, rather than focusing on specific regions or processes, as the purpose of this review is to inform a wider assessment of the risks to global food security. They concluded that anthropogenic greenhouse gas emissions and climate change have a number of implications for agricultural productivity but the aggregate impact of these is not yet known and indeed many such impacts and their interactions have not yet been reliably quantified, especially at the global scale.

The paper, **"Agricultural Sustainability" (2004),** was produced by the Agricultural and Natural Resources Team of the UK Department. The paper focuses on types of technology in particular settings, especially strategies that reduce reliance on non-renewable or environmentally harmful inputs. It focuses more on the concept of agricultural sustainability and goes beyond particular farming systems. It concluded that, given emerging pressures and resource constraints, agricultural policies need to simultaneously help meet the triple objective of poverty reduction, agricultural production and environmental sustainability. A major challenge is to create policies; institutional and technologies that make the three goals more compatible.

The document, **"Poverty and Climate Change: Reducing the vulnerability of the Poor through Adaptation",** has been written by a team consisting of **Piya, A., Vyas, Y. et. al., (2003).** The objective of this document is to contribute to a global dialogue on how to mainstream and integrate adaptation to climate change into poverty reduction efforts. They concluded that the first step is to ensure that the poor are able to adapt to current and imminent climate variability. The task ahead for the development community is to enhance the adaptive capacity of the poor and poor countries and to help to implement specific actions for addressing climate change impacts.

P. Das (2002), in his **paper, "Cropping Pattern (Agricultural and Horticultural) in Different Zones"** stated that multiplicity of cropping system has been one of main features of Indian agriculture and it is attributed to rainfed agriculture and prevailing socio-economic situations of farming community. It has been estimated that more than 250 double cropping systems are followed throughout the country and based on rationale of spread of crops in each district in the country, 30 important cropping systems have been identified.

Mendelsohn, R.; Dinar, A. and Sanghi, A. (2001), in their paper, **"The Effect of Development on the Climate Sensitivity of Agriculture"** examines the hypothesis, whether a country's stage of development affects its climate sensitivity?

The article uses the climate sensitivities of agriculture in the United States, Brazil and India for the analysis. This paper analyses the link between development and climate sensitivity. The analyses suggest that development may reduce climate sensitivity. The analysis does not directly link development to a change in climate sensitivity. It remains possible that other factors that also changed monotonically overtime could cause climate sensitivity to change. The paper also examines cross country effects. This analysis compares the climate sensitivity between India and United States. The result suggests that development does have an important effect on climate sensitivity.

Kavi Kumar, K.S. and Parikh Jyoti, (2001 a), in their study **"Socio-economic Impacts of Climate Change on Indian Agriculture"** uses an integrated modeling framework to assess the socio-economic impacts of climate change on Indian agriculture. The crop yield changes under various climate change scenarios are incorporated into an applied general equilibrium model of Indian economy to assess the welfare effects. The result indicates that the projected large scale changes in the climate would lead to significant reductions in crop yields, which in turn would adversely affect agricultural production. The result also shows that people in the poorer sections of the population are likely to bear a greater share of the burden imposed by climate change.

1.3 Objectives of the Study

In the light of the present research problem and on the basis of above review of literature following objectives of the study have been identified.

- To know the changes in the climate profile of the country.
- To find out the effects of climate change on crop yield as well as the production of crops.
- To identify current climate changes and their implications for agricultural system, rural livelihood and rural poor.

1.4 Hypotheses

- There is a change in the climate profile of the country.
- There is a decrease in crop yield as well as crop production due to changes in climate.
- Climate change has implications for agricultural system and rural poor.

1.5 Data Sources and Methodology

The methodology of this research is simple and based upon secondary data. The secondary data has been collected from statistical bulletin published by various organizations, books, journals, periodicals, newspapers, annual reports, etc. Given the severity of climate change-related problems in agriculture, there are inherent source limitations faced by farmers, landowners and resource managers, as well as the private and public sector institutions that support them. As in any environment where resources are constrained, a formal priority-setting methodology may be used to establish priorities among competing alternatives in order to meet private or social objectives.

1.6 Significance and Scope of the Study

The impacts of climate changes on agriculture and the farmers, rural households and communities which depend on agriculture can be expected to be particularly significant for two reasons. First, agriculture is directly and closely tied to its physical resource base and natural assets. Major changes in that resource base throughout much of the world widely threaten agricultural production and yields.

Second, many of the world's poor - particularly the rural poor - whose livelihoods are already precarious, are made more vulnerable by climate change for the simple reason that they are disproportionately dependent on agriculture and other natural resources for their livelihoods. More than 2.6 billion people are estimated to be directly dependent on agriculture and 600 million are dependent on livestock production; another 1.6 billion people are estimated to be dependent on forests for at least some portion of their income and still another 250 million people closely dependent on marine and inland fisheries (World Resources Institute, 2005; FAO, 2006).

Climate change and agriculture are interrelated processes, both which take place on a global scale (IPCC, 2007). Global warming is projected to have significant impacts on conditions affecting agriculture, including temperature, carbon dioxide, glacial run-off, precipitation and the interaction of these elements (Fraser, E. 2008). These conditions determine the carrying capacity of the biosphere to produce enough food for the human population and domesticated animals.

Food security has deteriorated since 1995 and reductions in child malnutrition are unlikely to reach targets set by the millennium development goals (MDGs) by 2015. Climate change will have a significant impact on food security and malnutrition, as changes in patterns of extreme weather events will affect the stability of, and indeed access to, food supplies (Cohen, 2008).

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Chapter-2
Climate of India

CLIMATE OF INDIA

2.1 Introduction

India is a land of diverse climatic regions. The Indian climate ranges from tropical in the south to temperate and alpine in the Himalayan in north. The hilly areas receive continuous winter snowfall. The climate of the country is largely influenced by the Himalayas in the north and the Thar Desert in south. The Himalayas act as a barrier to the downwards moving cold winds flowing down from Central Asia that keeps the bulk of the Indian subcontinent warmer than most locations at similar latitudes. Land areas in the north of the country have a continental climate with severe summer conditions that alternate with cold winter when temperatures fall to freezing point. Opposite to this the coastal regions of the country are humid and the rains are frequent.

India can be classified as a hot tropical country, except the northern states of Himachal Pradesh and Jammu & Kashmir in the north and Sikkim in the northeastern hills, which have a cooler, more continental influenced climate. In most of India summer is very hot. It begins in April and continues till the beginning of October. The heat peaks in June with temperatures in the northern plains and the west reach 45^0C and more. The monsoon hit the country during this period, beginning first of June when they are supposed to find the Kerala coast, moving further inland from day to day. Moisture laden trade winds sweep the country bringing heavy rains and thunderstorms, sometimes these monsoon rains can be very heavy, causing flooding and damage, especially along the big rivers of India, Brahmaputra and Ganges.

The plains in the north and even the barren countryside of Rajasthan have a cold wave every year in December-January. Minimum temperatures could dip below 5^0C but maximum temperature usually not fall lower than 12^0C. In the northern high altitude areas of the northern mountains, it snows through the winter, and even summer months are only mildly warm (www.weatheronline.in).

Monsoon is a major weather phenomenon in India (and the subcontinent) for the influence it casts on the lives of its inhabitants for centuries. Monsoon in India can be categorized into two branches based on their spatial spread over the sub-continent- Arabian Sea Branch and Bay of Bengal Branch. Alternatively, it can be categorized into two segments based on the direction of rain bearing winds- South-West Monsoon and North-East Monsoon. This we discuss in the rainfall section of this chapter.

Climatic hazards have always been a foremost matter of concern to the human population. Although there have been significant achievements in science and technology in the 20th century, people still continue to suffer the consequence of severe floods and droughts on all continents. Floods endanger human life, cause damage to settlements and transport networks, and destroy human heritage. Devastating droughts are harmful for agriculture and may create problems in water supply. Droughts can be connected with heat waves, i.e., extended time intervals of abnormally and uncomfortably hot weather lasting from several days to several weeks, which can be harmful for human health.

According to the World Water Council (WWC), economic losses from weather and floods catastrophes have increased ten-fold over the past 50 years, partially as a result of rapid climate changes. These rapid climate changes are seen in more intense rainy seasons, longer dry seasons, stronger storms, shifts in rainfall seasons, and rising sea levels. More disastrous floods and droughts have been the most visible manifestation of these changes (Eisenriech, 2005).

In view of the developing issues of climate change, floods and droughts may become more frequent. Climate change has the potential to increase the frequency of extreme events globally by increasing flood risks in some region, increasing drought risk in others, and even increasing the occurrence of both flood and drought in some parts of the world (IPCC 2007 b).

There is a large number of variables that comprise the climate of a region like rainfall, temperature, wind and wind's speed, pressure, vegetation, topography etc. However it is difficult to discuss all. In the present chapter to know the change in climate, only four variables have been taken under consideration that is rainfall, temperature, flood and drought because these are those variables that affect the other variables largely.

2.2 Rainfall

The country is influenced by two seasons of rains, namely southwest monsoon (June to September) and the northeast monsoon (October to December). The monsoon accounts for 80 percent of the rainfall in India (en.m.wikipedia.org). The pattern, withdrawal and amount of rainfall during the monsoon season have crucial impact on water resources, power generation, agriculture, other economic activities and ecosystem in the country. Indian agriculture which accounts for 14 percent of GDP (Economic Survey, 2012-13) is heavily dependent on the rain, for growing crops especially like cotton, rice, oil seeds and coarse grains. A delay of a few days in the arrival of the monsoon can badly affect the economy. The variation in climate conditions of India is perhaps greater than any other country of similar size in the world. There is a large variation in the amounts of rainfall received at different locations. The average annual rainfall is less than 13 cm over the western Rajasthan while as much as 1141 cm in the Meghalaya. The rainfall pattern roughly reflects the different climate regimes of the country which vary from humid in the northeast (about 180 days rainfall in a year), to arid in Rajasthan (20 days rainfall in a year) (Attri and Tyagi, 2010).

2.2.1 Southwest Monsoon Rainfall

Consequent to the intense heat of the summer months, the northern Indian landmass becomes hot and draws moist winds over the oceans causing a reversal of the winds over the region which is called the southwest monsoon. This is most important feature controlling the Indian climate because about 75 percent of the annual rainfall is received during a short span of four months (June, July, August and September) (Attri and Tyagi, 2010). In India the monsoon season is so significant that the remaining seasons are often referred relative to the monsoon.

The southwest monsoon is generally expected to begin around the beginning of June and fade away by the end of September. The moisture laden winds on reaching the southernmost point of the Indian Peninsula, due to its topography, become divided into two parts: the Arabian Sea Branch and the Bay of Bengal Branch.

The Arabian Sea Branch of the Southwest Monsoon first hits the Western Ghats of the coastal state of Kerala, India, thus making this area the first state in India to receive rain from the Southwest Monsoon. This branch of the monsoon moves northwards along the Western Ghats (Konkan and Goa) with precipitation on coastal area, west of the Western Ghats. The eastern areas of the Western Ghats do not receive much rain from this monsoon as the wind does not cross the Western Ghats.

The Bay of Bengal Branch of Southwest Monsoon flows over the Bay of Bengal heading towards North-East India and Bengal, picking up more moisture from the Bay of Bengal. The winds arrive at the Eastern Himalayas with large amounts of rain.

Mawsynram, situated on the southern slopes of the Khasi Hills in Meghalaya, India, is one of the wettest places on Earth (en.m.wikipedia.org).

The rainfall during southwest monsoon oscillates between active spells associated with widespread rains over most parts of the country and breaks with little rainfall activity over the plains and heavy rains across the foothills of the Himalayas. Heavy rainfall in the mountainous catchments under 'break' conditions results flooding over the plains. For the country as whole, mean monthly rainfall during July (286.5mm) is highest and contributes about 24.2 percent of annual rainfall (1182.8mm). The mean rainfall during August is slightly lower and contributes about 21.2 percent of annual rainfall. June and September rainfall are almost similar and contributes 13.8 percent and 14.2 percent of annual rainfall respectively. Taking together the mean rainfall of these months contributes 74.2 percent of annual rainfall (1182.8 mm) (Attri and Tyagi, 2010).

2.2.2 Northeast Monsoon Rainfall

Northeast Monsoon is associated with the establishment of the north-easterly wind regime over the Indian subcontinent. Around September, with the sun fast retreating south, the northern landmass of the Indian subcontinent begins to cool off rapidly. With this air pressure begins to build over northern India, the Indian Ocean and its surrounding atmosphere still holds its heat. This causes cold winds to sweep down from the Himalayas and Indo-Gangetic Plain towards the vast spans of the Indian Ocean south of the Deccan Peninsula. This is known as the Northeast Monsoon. While traveling towards the Indian Ocean, the dry cold wind picks up some moisture from the Bay of Bengal and pours it over peninsular India and parts of Sri Lanka. Cities like Chennai, which get less rain from the Southwest Monsoon, receive rain from this Monsoon. About 50 percent to 60 percent of the rain received by the State of Tamil Nadu is from the Northeast Monsoon (en.m.wikipedia.org).

Meteorological subdivisions namely Coastal Andhra Pradesh, Rayalaseema, Tamil Nadu, Kerala and South Interior Karnataka receive good amount of rainfall accounting for about 35 percent of their annual total in these months. Many parts of Tamil Nadu and some parts of Andhra Pradesh and Karnataka receive rainfall during these months due to storms forming in the Bay of Bengal. These months are the main rainfall period for Tamil Nadu during which nearly 47 percent of the annual total 91 cm is received. Further, the coastal districts of Tamil Nadu normally receive about 75-100 cm of rainfall during these months thereby contributing nearly 60 percent of their annual total. Contribution of rainfall of October, November and December for the country as a whole in annual rainfall is mostly the same as of March, April and May (11 percent) (Attri and Tyagi, 2010).

2.2.3 Change in Rainfall

The all India annual and monsoon rainfall for the period 1901-2009 for the country as a whole do not show any significant trend. Similarly rainfall for the country as a whole for the same period for individual monsoon months also does not show any significant trend. The alternating sequence of multi-decadal periods of thirty years having frequent droughts and flood years are observed in the All India Monsoon Rainfall data. The decades 1961-70, 1971-80 and 1981-90 were dry periods. However the decade 1991-2000 experienced wet period (Attri and Tyagi, 2010).

However, during the winter season, rainfall is decreasing in almost all the subdivisions except for the sub-divisions Himachal Pradesh, Jharkhand and Nagaland, Manipur, Mizoram & Tripura. Rainfall is decreasing over most parts of the central India during the pre-monsoon season. However during the post-monsoon season, rainfall is increasing for almost all the sub-divisions except for the nine-sub divisions.

The All India Rainfall Distribution from 2000-01 to 2012-13 is given in following tables. The rainfall is given for Monsoon season, Post-Monsoon season, Winter season and Pre-Monsoon season separately and also over all rainfall from June to May. Rainfall is given in millimetres.

Table-2.1

All India Rainfall Distribution during Monsoon Season

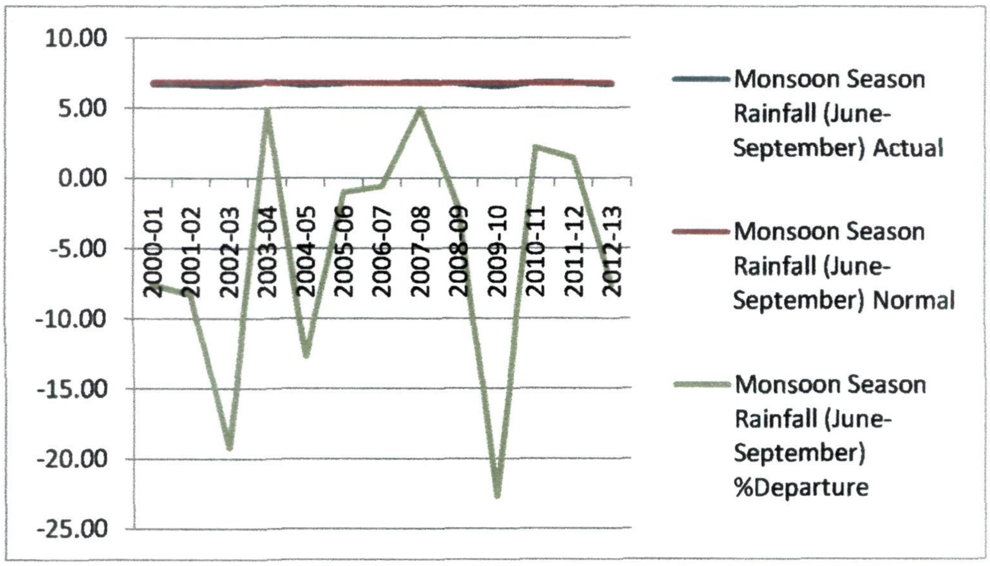
From 2000-01 to 2012-13

Year	Monsoon Season Rainfall (June – September) (in millimetres)		
	Actual	Normal	Percentage Departure
2000-01	833.7	902.3	-7.6
2001-02	826.0	901.1	-8.3
2002-03	737.1	911.7	-19.2
2003-04	947.3	902.7	4.9
2004-05	779.6	893.3	-12.7
2005-06	879.3	892.5	-1.0
2006-07	886.6	892.2	-0.6
2007-08	936.9	892.2	5.0
2008-09	873.2	892.2	-2.1
2009-10	689.8	892.2	-22.7
2010-11	912.8	893.2	2.2
2011-12	899.9	887.5	1.4
2012-13	819.5	886.9	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in.

Figure- 2.1

Rainfall during Monsoon Season from 2000-01 to 2012-13



According to the table-2.1, the monsoon rainfall in 2000-01 was 833.7 mm (actual) and 902.3 mm (normal) so the percentage departure was -7.6 during this year. Rainfall decreases to 826.0 mm (actual) in 2001-02 and again to 737.1 mm in 2002-03. In 2003-04 it increases to 947.3 mm. But again in 2004-05, it decreases to 779.6 mm. Actual rainfall in 2005-06 was 879.3 mm which increases to 886.6 mm in 2006-07 and to 936.9 mm in 2007-08. In 2008-09 rainfall of the monsoon season declines to 873.2 mm and to 689.8 mm in 2009-10. In 2010-11 again rainfall increases to 912.8 mm but then declines to 899.9 mm in 2011-12. In 2012-13 the actual monsoon rainfall was 819.5 mm, while the normal rainfall was 886.9 mm and so the percentage departure was -7.6.

The above explanation can be better understood with the help of line graph shown in above figure-2.1.

Table-2.2

All India Rainfall Distribution during Post-Monsoon Season

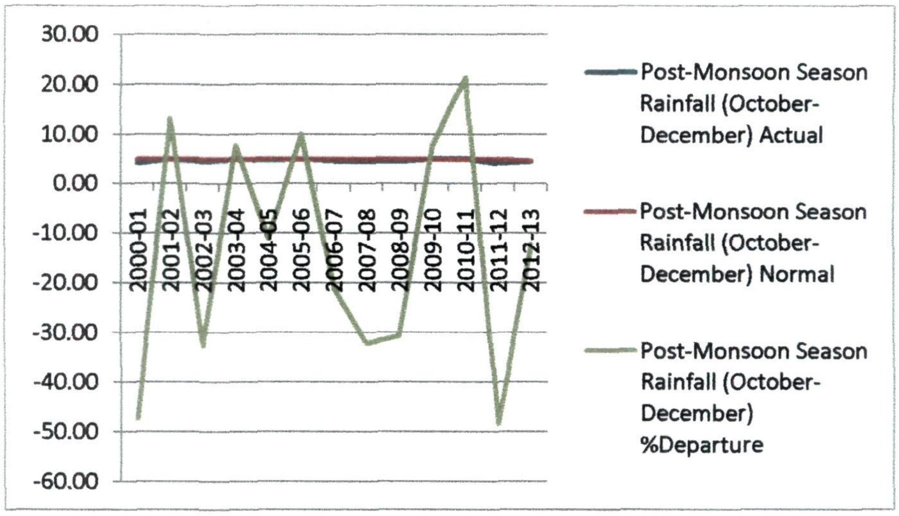
From 2000-01 to 2012-13

Year	Post-Monsoon Season Rainfall (October – December) (in millimetres)		
	Actual	**Normal**	**Percentage Departure**
2000-01	64.1	121.7	-47.3
2001-02	137.7	121.7	13.1
2002-03	83.4	123.7	-32.6
2003-04	134.6	125.0	7.7
2004-05	111.8	125,7	-11.1
2005-06	138.4	125.8	10.0
2006-07	99.3	125.9	-21.1
2007-08	85.4	125.9	-32.2
2008-09	87.2	125.9	-30.7
2009-10	135.5	125.9	7.6
2010-11	153.2	126.3	21.3
2011-12	65.7	127.2	-48.8
2012-13	85.4	97.4	-12.3

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in.

Figure- 2.2

Rainfall during Post-Monsoon Season from 2000-01 to 2012-13



As shown in the table-2.2, the post-monsoon rainfall in 2000-01 was 64.1 mm (actual) and 121.7 mm (normal) and percentage departure was -47.3 which are much less than the monsoonal rainfall. In 2001-02 rainfall increases to 137.7 mm but declines to 83.4 mm in 2002-03. Once again in 2003-04 rainfall increases to 134.6 mm and then declines to 111.8 mm in 2004-05. In 2005-06, actual rainfall of this season was 138.4 mm which declines to 99.3 mm in 2006-07 and to 85.4 mm in 2007-08 then slightly increase to 87.2 mm in 2008-09. In 2009-10 rainfall was 135.5 mm which increase to 153.2 mm in 2010-11 but again declines to 65.7 mm in 2011-12 and then increase to 85.4 mm in 2012-13 as against the normal rainfall 97.4 mm during this year.

The above explanation can be better understood with the help of line graph shown in above figure-2.2.

Table-2.3

All India Rainfall Distribution during Winter Season

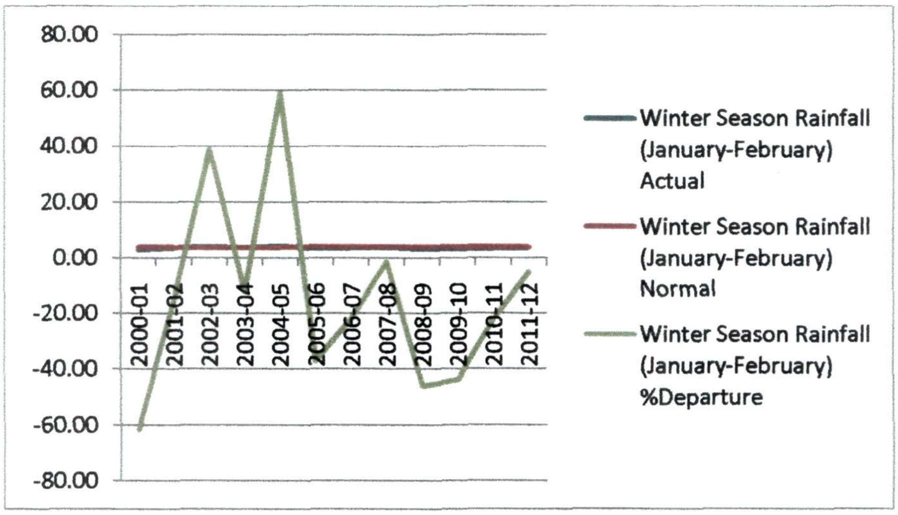
From 2000-01 to 2011-12

Year	Winter Season Rainfall (January– February) (in millimetres)		
	Actual	Normal	Percentage Departure
2000-01	16.2	42.2	-61.6
2001-02	35.0	41.2	-15.0
2002-03	53.2	38.3	38.9
2003-04	34.5	39.2	-12.0
2004-05	69.8	43.8	59.0
2005-06	27.8	43.9	-37.0
2006-07	34.3	43.8	-21.7
2007-08	42.6	43.2	-1.4
2008-09	23.6	43.8	-46.1
2009-10	24.6	43.8	-43.8
2010-11	31.9	40.9	-22.0
2011-12	38.8	40.9	-5.1

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in.

Figure- 2.3

Rainfall during Winter Season from 2000-01 to 2011-12



The rainfall of winter season is much less as compared to monsoon-season, and post-monsoon season. As given in the table-2.3. The actual rainfall during this season was 16.2 mm as against the normal rainfall 42.2 mm in 2000-01 which increases to 35.0 mm in 2001-02 and to 53.2 mm in 2002-03 but decline to 34.5 mm in 2003-04. Again in 2004-05 it increases to 69.8 mm but declines to 27.8mm in 2005-06. In 2006-07 rainfall was 34.3 mm and increases to 42.6 mm in 2007-08. In 2008-09 rainfall was 23.6 mm and 24.6 mm in 2009-10. Again it increases to 31.9 mm in 2010-11 and again increases to 38.8 mm in 2011-12 with -5.1 percentage departure having normal rainfall equal to 40.9 mm during winter season of this year.

The above explanation can be better understood with the help of line graph shown in above figure-2.3.

Table-2.4

All India Rainfall Distribution during Pre-Monsoon Season

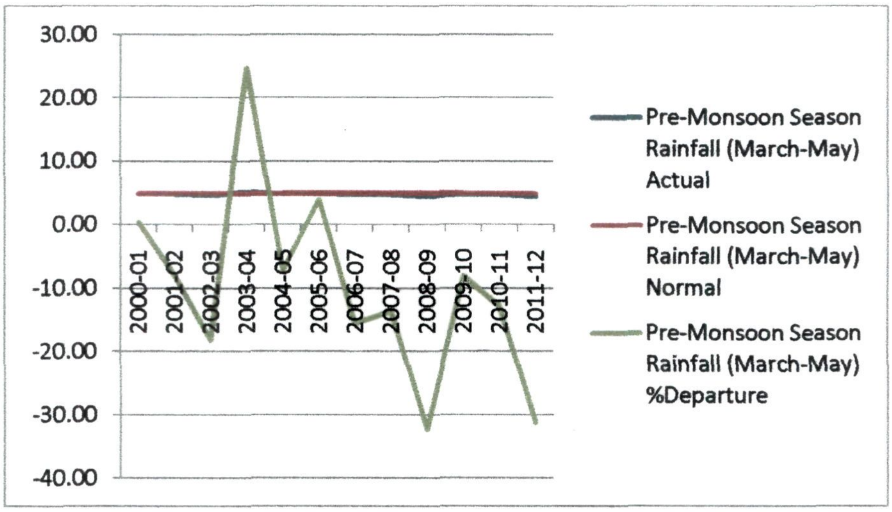
From 2000-01 to 2011-12

Year	Pre-Monsoon Season (March – May) (in millimetres)		
	Actual	**Normal**	**Percentage Departure**
2000-01	129.7	129.3	0.3
2001-02	121.5	132.0	-8.0
2002-03	107.7	131.7	-18.2
2003-04	161.6	129.6	24.7
2004-05	124.7	134.5	-7.3
2005-06	139.9	134.6	3.9
2006-07	112.8	133.6	-15.6
2007-08	115.3	133.5	-13.6
2008-09	91.0	134.5	-32.3
2009-10	122.9	133.7	-8.1
2010-11	114.4	131.3	-12.9
2011-12	90.3	131.3	-31.2

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in.

Figure- 2.4

Rainfall during Pre-Monsoon Season from 2000-01 to 2011-12



The rainfall during pre-monsoon season is more than post-monsoon season and winter season but less than monsoon season rainfall. It is clear from the table-2.4 that, the actual rainfall of pre-monsoon season in 2000-01 was 129.7 mm while normal rainfall was 129.3 mm which declines to 121.5 mm and 132.0 mm respectively in 2001-02 and to 107.7 mm (actual) in 2002-03. In 2003-04 rainfall of this season increases to 161.6 mm but declines to 124.7 mm in 2004-05 but again increases to 139.9 mm in 2005-06. In 2006-07, the rainfall was 112.8 mm which slightly increases to 115.3 mm in 2007-08. Again in 2008-09 rainfall declines to 91.0 mm and increases to 122.9 mm in 2009-10. In 2010-11, rainfall was 114.4 mm which declines to 90.3 mm in 2011-12 which was much less than normal rainfall 131.3 mm during this year and so the percentage departure was -31.2.

The above explanation can be better understood with the help of line graph shown in above figure-2.4.

Table-2.5

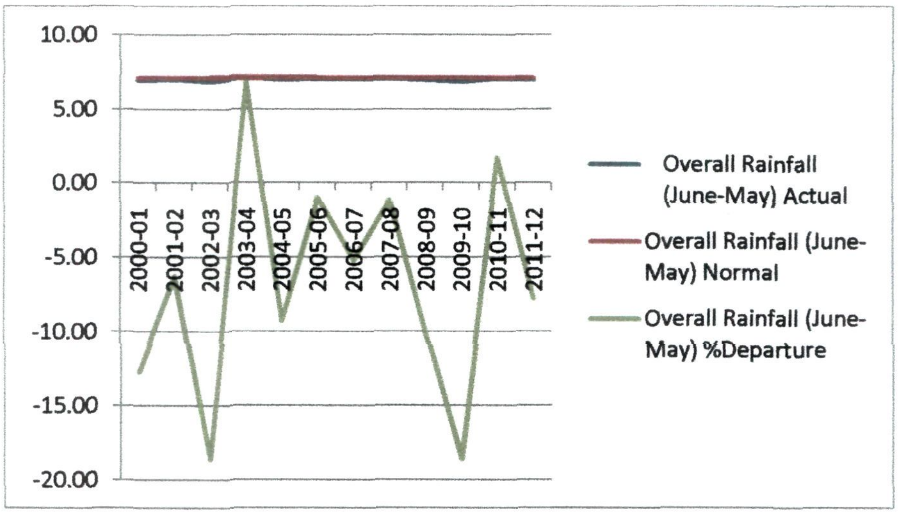
All India Overall Rainfall Distribution from 2000-01 to 2011-12

Year	Overall Rainfall (June – May) (in millimetres)		
	Actual	Normal	Percentage Departure
2000-01	1043.7	1195.5	-12.7
2001-02	1120.2	1196.0	-6.3
2002-03	981.4	1205.4	-18.6
2003-04	1278.0	1196.5	6.8
2004-05	1085.9	1197.3	-9.3
2005-06	1185.4	1196.8	-1.0
2006-07	1133.0	1195.5	-5.2
2007-08	1180.2	1194.8	-1.2
2008-09	1075.0	1196.4	-10.1
2009-10	972.8	1195.6	-18.6
2010-11	1212.3	1191.7	1.7
2011-12	1094.7	1186.9	-7.8

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in.

Figure- 2.5

Overall Rainfall Distribution from 2000-01 to 2011-12



If we see the overall rainfall of India from June to May, given in table-2.5 it was 1043.7 mm in 2000-01, which increased to 1120.0 mm in 2001-02 and then declines to 981.4 mm in 2002-03. Again it increases to 1278.0 mm in 2003-04, and then declines to 1085.9 mm in 2004-05. In 2005-06, the overall rainfall of India was 1185.4 mm which slightly declined to 1133.0 mm in 2006-07 and then slightly increased to 1180.2 mm in 2007-08. In 2008-09 rainfall declines to 1075.0 mm and again to 972.8 mm in 2009-10. In 2010-11 actual rainfall from June to May was 1212.3 mm which declined to 1094.7 mm in 2011-12.

The above explanation can be better understood with the help of line graph shown in above figure-2.5.

2.2.4 Distribution of Monsoon Rainfall

The distribution of Monsoon rainfall in India is uneven both regionally and seasonally. Moreover, it is undependable as its occurrence is not at stipulated times. Unevenness of Monsoonal rainfall in India is described below: (www.preservearticles.com)

2.2.4.1 Regional Unevenness

Regional unevenness in Indian rainfall is described in the following terms:

- The heaviest rainfall in the world is received by Mawsynram. Mawrynram is a village in the East Khasi Hills, district of Meghalaya state in north-eastern India. Here the annual rainfall exceeds 1080 cm. On the contrary, there are also places in India which receive the least rainfall. Barmer in Thar Desert receives only less than 12 cm annual rainfall. Sometimes it also happens that the western – most part of Rajasthan Desert does not experience even a single centimetre of rainfall for years together (DES, DAC, 2013).

- In the Great Plains of the North (the Ganga – Yamuna Plains) monsoonal rainfall goes on decreasing from east to west during the period of Southwest monsoon. Rainfall on Assam hills exceeds 250 cm while Bihar plains receives only 125 to 150 cm rainfall. In Punjab it decreases to 75 cm only (DES, DAC, 2013).

- In the Peninsular India monsoonal rainfall decreases from west to east. Western slopes of the Western Ghats enjoys more than 250 cm of Monsoonal rainfall. Rainfall decreases from 75 to 100 cm on the eastern slopes of the Western Ghats. It further comes down in the Maidan region of Karnataka, thus putting it in the rain shadow areas of the Southwest monsoon. Here rainfall is only 40 to 60 cm (DES, DAC, 2013).

- During winter also, regional variations are found in rainfall distribution; North-West India obtains up to 25 cm of winter rainfall while on the coast of Tamil Nadu as much as 75 cm winter rainfall occurs. In other parts of the country winter rainfall is negligible (DES, DAC, 2013).

2.2.4.2 Seasonal Unevenness

Seasonal unevenness in the monsoonal rainfall of India is revealed in the following accounts:

- During summer and rainy season India receives 75 percent to 85 percent of the total annual rainfall while only 15 percent to 25 percent of the total annual rainfall is obtained in the remaining period of the year. Southwest monsoon provides rains in summer and rainy season while Northeast monsoon and western disturbance cause winter rainfall (DES, DAC, 2013).

- Tropical cyclones bring rainfall on the coastal region in summer and in the season of retreating monsoon.

2.3 Temperature

India is characterized by strong temperature variations in different seasons ranging from mean temperature of about 10^0C in winter to about 32^0C in summer season. India Meteorological Department (IMD) has categorized the month of January and February as winter season. These months are associated with clear sky, fine weather, light northerly winds, low humidity and temperatures, and large daytime variations of temperature. The cold air mass extending from the Siberian region has profound influence on the Indian subcontinent during these months. The mean temperatures vary from 14^0C to 27^0C during January. The mean daily minimum temperature ranges from 22^0C in the extreme south, to 10^0C in the northern plains and 6^0C in Punjab (Attri and Tyagi, 2010).

The temperatures start to increase all over the country in March and by April, the interior parts of the peninsula record mean daily temperatures of 30-35^0C. Central Indian landmass becomes hot with daytime maximum temperatures reaching about 40^0C at many locations. Many stations in Gujarat, North Maharashtra, Rajasthan and North Madhya Pradesh exhibit high day-time and low night-time temperatures during these months. The range of the day-time maximum and night-time minimum temperatures is found more than 15^0C at many stations in these states. Maximum temperature rise sharply exceeding 45^0C by the end of May and early June resulting in harsh summers in the north and north-west regions of the country. However, weather remains mild in coastal areas of the country owing to the influence of land and sea breezes (Attri and Tyagi, 2010).

The months of October, November and December are associated with the establishment of the north-easterly wind regime over the Indian subcontinent. The day temperatures during these months start falling sharply all over the country. The mean temperatures over north western parts of the country show decline from about 38^0C in October to 28^0C in November. Decrease in humidity levels and clear sky over most parts of north and central India after mid-October are the characteristics features of this season (NATCOM 2004, IMD 2010).

2.3.1 Change in Temperature

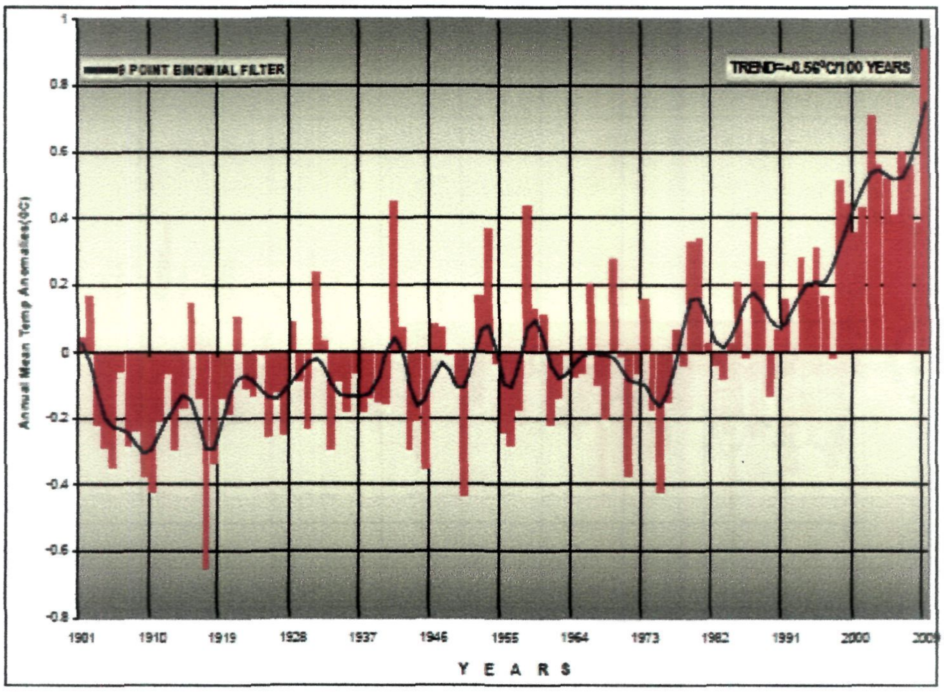
India Meteorological Department (IMD) maintains a well distributed network of more than 500 stations in the country for more than a century, the salient findings of the IMD studies (IMD annual climate summary, 2009, Tyagi and Goswami, 2009, Attri 2006), are summarized as under:

Analysis of data for period 1901-2009 suggests that annual mean temperature for the country as a whole has risen by 0.56^0 (Fig. 2.6) over the period. It may be mentioned that mean temperature has been generally above (normal based on period, 1961-1990) since 1990. This warming is primarily due to rise in maximum temperature across the country, over larger parts of the data set (Fig. 2.7). However, since 1990, minimum temperature is steadily rising (Fig. 2.8) and rate of its rise is slightly more than that of maximum (IMD annual climate summary, 2009). Warming trend over globe of the order of 0.74^0C has been reported by IPCC (2007). The mean annual temperature shows significant positive (increasing) trend over parts of the country except over parts of Rajasthan, Gujarat and Bihar, where significant negative (decreasing) trends were observe (IMD annual climate summary, 2009).

Season wise, maximum rise in mean temperature (Fig. 2.9) was observed during the post-monsoon season (0.77^0C) followed by winter season (0.70^0C), pre-monsoon season (0.64^0) and monsoon season (0.33^0C). During the winter season, since 1991, rise in minimum temperature is appreciably higher than that of maximum temperature over northern plains. This may be due to pollution leading to frequent occurrences of fog. Upper air temperatures have shown an increasing trend in the lower troposphere, while decreasing trend was observed in the upper troposphere (Kothwale and Rupa Kumar, 2002).

Figure- 2.6

All India Annual Mean Temperature Anomalies for the period 1901-2009



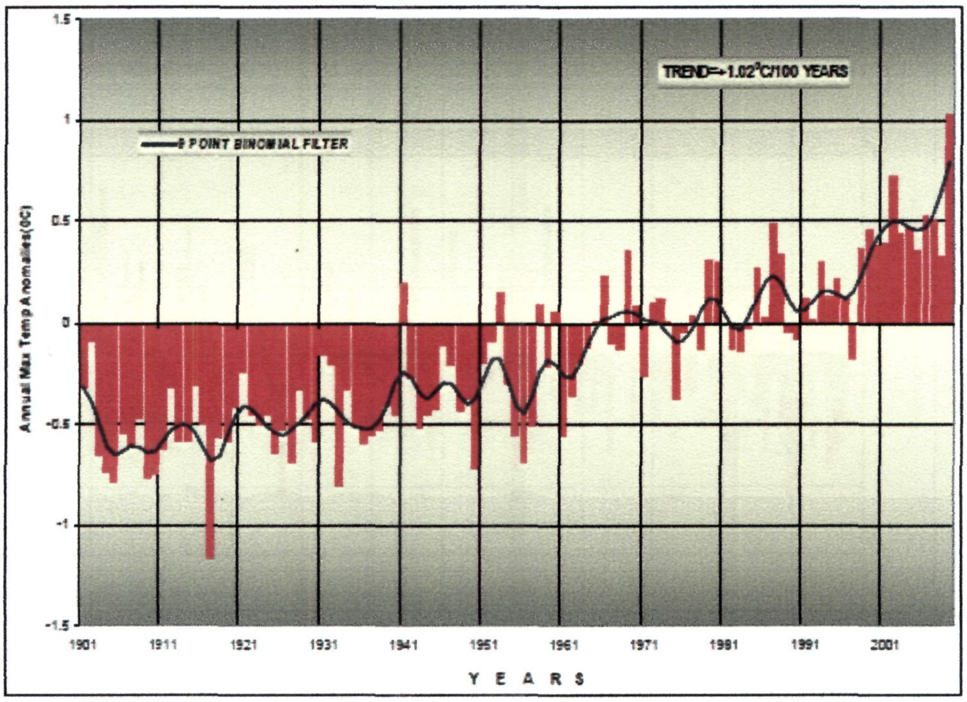
All India annual mean temperature anomalies for the period 1901-2009 (based on 1961-1990 average) shown as vertical bars.

(The Solid curve show sub-decadal time scale variations smoothed with a binomial filter)

Source: Climate Profile of India (2010), India Meteorological Department.

Figure- 2.7

All India Annual Maximum Temperature Anomalies for the period 1901-2009



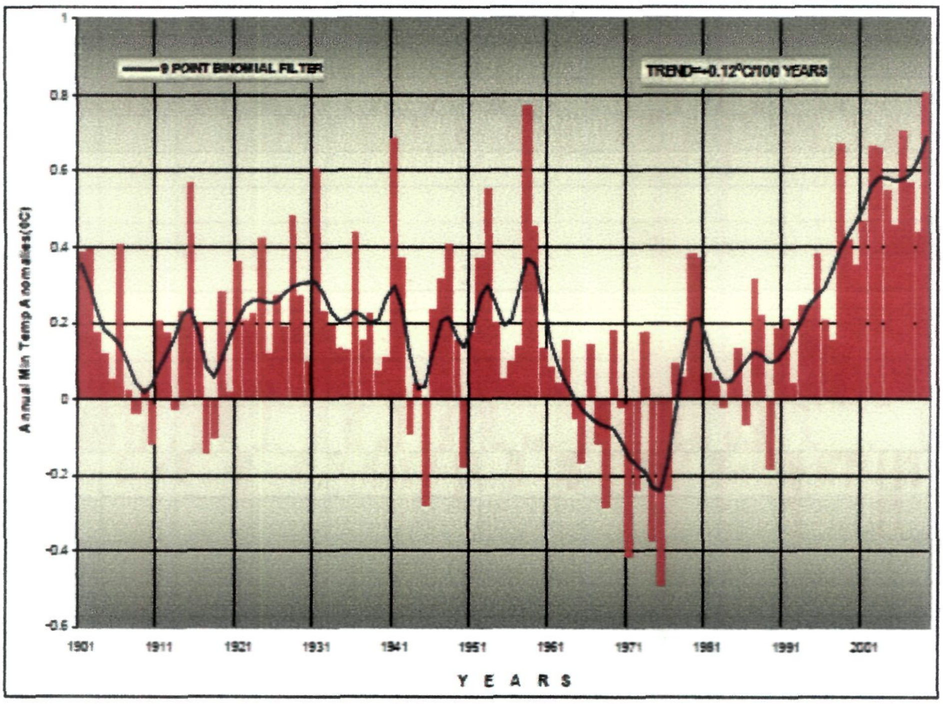
All India annual maximum temperature anomalies for the period 1901-2009 (based on 1961-1990 average) shown as vertical bars.

(The solid curve show sub-decadal time scale variations smoothed with a binomial filter)

Source: Climate Profile of India (2010), India Meteorological Department.

Figure- 2.8

All India Annual Minimum Temperature Anomalies for the period of 1901-2009



All India annual minimum temperature anomalies for the period of 1901-2009 (based on 1961-1990 average) shown as vertical bars.

(The solid curve show sub-decadal time scale variations smoothed with a binomial filter)

Source: Climate Profile of India (2010), India Meteorological Department.

Figure- 2.9

All India Mean Temperature Anomalies for the four seasons for the period 1901-2009

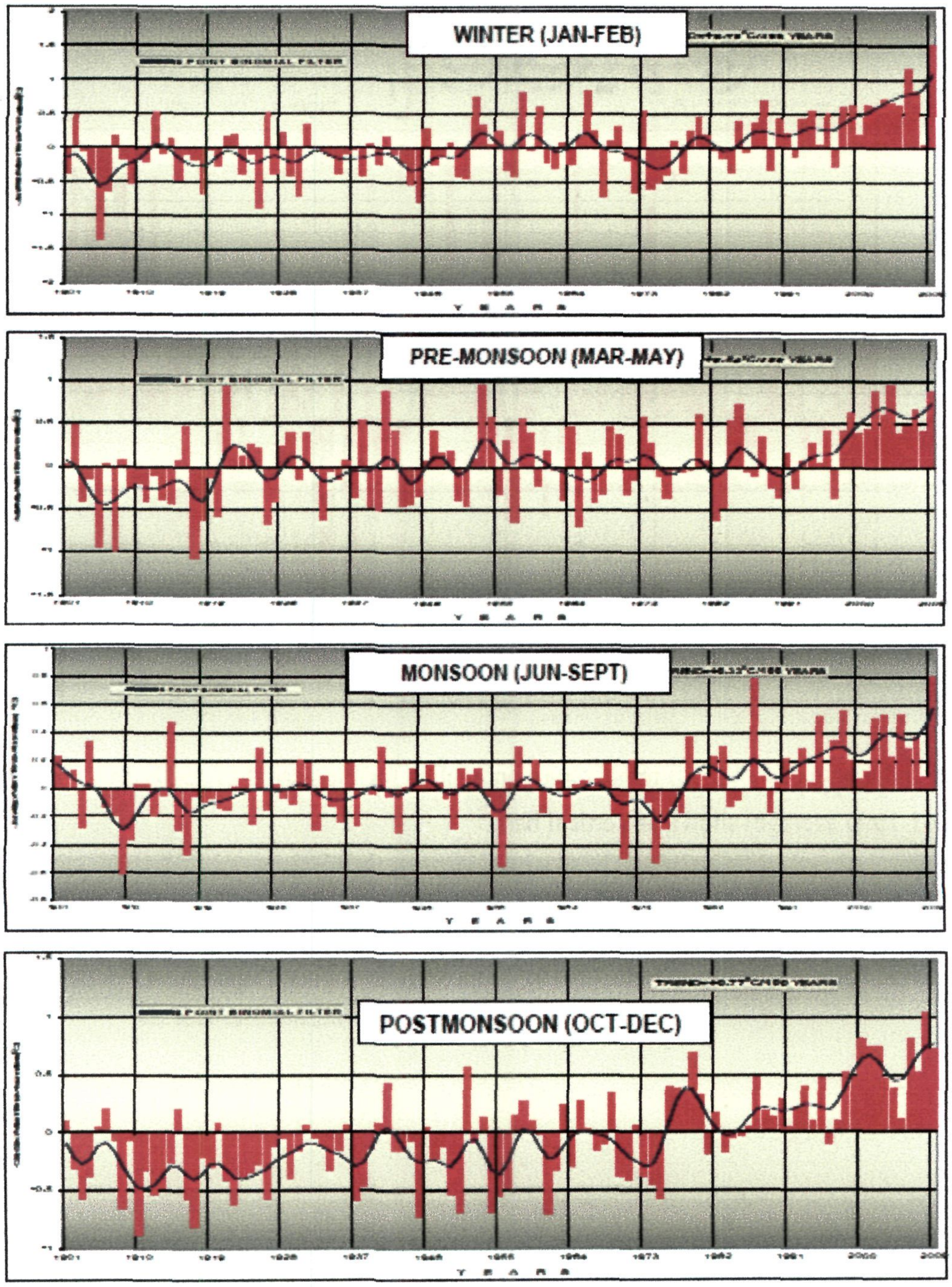


Fig. 2.9: All India Mean Temperature Anomalies for the four seasons for the period 1901-2009 (Based on 1961-1990 average) shown as vertical bars.

Source: Climate Profile of India (2010), India Meteorological Department.

2.3.2 Region wise Temperature Change

A tropical rainy climate governs region experiencing persistent warm or high temperature, which normally does not fall below 18^0C. Winter and early summer are long are dry period, with temperature averaging above 18^0C. Summer is exceedingly hot, temperatures in low-lying areas may exceed 50^0C during May, leading to heat waves that can kill hundreds of Indians. Change in temperature in different region is summarized below: (en.m.wikipedia.org)

In **Tamil Nadu,** the coolest month of the year, on average, is January; April and May are the warmest months. Average temperatures in January range from 14^0C to 25^0C, and average temperatures in April range from 25^0C to 35^0C, July is on average the wettest month. In December, the coldest month, temperatures still average around 20^0C to 24^0C. The months during March to May are hot and dry, mean monthly temperatures hover around 32^0C with 320 mm precipitation.

Most of **Western Rajasthan** experiences an arid climatic regime. The summer months of May and June are exceptionally hot; mean monthly temperatures in the region hover around 35^0C, with daily maxima occasionally topping 50^0C. During winter, temperatures in some areas can drop below freezing due to waves of cold air from Central Asia.

To the **West in Gujarat**, diverse climate conditions obtain. The winters are mild, pleasant, and dry with average day-time temperatures around 29^0C and night around 12^0C with virtually full sun and clear nights. Summers are hot and dry with day-time temperature around 41^0C and night no lower than 29^0C. In the weeks before the monsoon, temperatures are similar to the above, but high humidity makes the air more uncomfortable. Relief comes with the monsoon. Temperatures are around 35^0C but humidity is very high, nights are around 27^0C.

East of the **Thar Desert**, the **Punjab – Haryana – Kathiawar** region experiences a tropical and sub-tropical steppe climate. Haryana's climate resembles other states of the northern plains: extreme summer heat of upto 50^0C and winter cold as low as 1^0C. May and June are hottest; December and January are coldest. In Punjab, temperatures typically range from -2^0C to 40^0C, but can reach 47^0C in summer and -4^0C in winter.

Most of **Northeast India** and much of **North India** are subject to a humid subtropical climate. Though they experience hot summers, temperatures during the coldest months may fall as low as 0^0C. The rest of North India, including the Indo-Gangetic Plain, almost never receives snow. Temperatures in the plains occasionally fall below freezing, though never for more than one or two days. Winter's high temperature in **Delhi** ranges from 16^0C to 21^0C. Night-time temperature is $2\text{-}8^0$C.

Eastern India's climate is much milder, experiencing moderately warm days and cool nights. Highest temperature ranges from 21^0C in **Patna** to 23^0C in **Kolkata** and lowest average temperature ranges from 7^0C in **Patna** to 9^0C in **Kolkata**.

In **South India**, particularly **Maharashtra, Madhya Pradesh,** parts of **Karnataka,** and **Andhra Pradesh,** somewhat cooler weather prevails. Minimum temperatures in **Western Maharashtra, Madhya Pradesh and Chhattisgarh** hover around 10^0C; in the southern Deccan Plateau they reach 16^0C. Coastal areas are warm, with daily high temperature of 30^0C and low of around 21^0C.

The **Western Ghats**, including **Nilgiri Range**, are exceptional; their low temperature can fall below freezing.

2.4 Floods

Floods are caused by extremely intense or extremely long rainfall events, by intense snowmelts, or a combination of both. Floods are usually followed by inundation, when water skills beyond the river channel. Floods are caused by the inadequate capacity within the banks of the rivers to contain the high flows brought down from the upper catchments due to heavy rainfall. In coastal areas, they are caused by cyclones and typhoons. Other causes include backing up of waters in tributaries at their outfalls into the main river often with synchronization of floods in them; ice jams or landslides blocking stream courses resulting in the backwater overflowing river banks. Flash flood occurs in areas near foot hills. However the root cause of flood is excessive rainfall which occurs mainly in the monsoon months of July to September. Floods are also sometimes caused by Glacial Lake Outburst called Glacial Lake Outburst Floods (GLOFs) which can be catastrophic for people living immediately downstream and can cause serious damage to infrastructure and the economy.

Floods are recurrent phenomena since time immemorial. Almost every year some parts of the world or the other are affected by the floods of varying magnitude. Even in the same country of the region, different parts have different climates and rainfall patterns and, as such, it is also experienced that while some parts are suffering under devastating floods, another part is suffering under drought. With the increase in population and developmental activity, there has been tendency to occupy the flood plains which has resulted in more serious nature of damages over the years. Because of the varying rainfall distribution, many times, areas which are not traditionally prone to floods also experience severe inundation. Flood indeed is the single most frequent disaster faced not only in India but by various part of world including the South Asia region.

Floods inundate the banks, destroy crops, damage properties, perish livestock, disturb communication and power supply and endanger human life. Floods are followed by epidemics. Supply of drinking water and restore sanitation are post flood challenge. The flood problem in India is mostly confined to the states located in the Indo-Gangetic plains, northeast India and occasionally in the rivers of Central India. Heavy rainfall, inadequate capacity of rivers to carry the high flood discharge, inadequate drainage to carry away the rainwater quickly to streams/rivers, storm surges, Man-made factors such as failure of dams and other control works like reservoirs are the main causes of floods.

Rashtriya Barh Ayog (RBA) constituted by the Government of India in 1976 carried out an extensive analysis to estimate the flood-affected area in the country. RBA in its report (1980) has assessed the area liable to floods as 40 million hectares. It was determined by summing up the maximum area affected by floods in any one year in each state during the period from 1953 to 1978 for which data was analyzed by the RBA. This sum has been corrected for the area that was provided with protection at that time and for the protected area that got affected due to failure of protection works during the period. The area affected by flood in the country from 1955 to 2010 is depicted in following Table-2.6.

Table-2.6
Flood Affected Area (Million Hectares) During 1955-2007

Year	Flood Affected Area
1955	9.44
1960	7.53
1965	1.46
1970	8.46
1975	6.17
1980	11.46
1985	8.38
1990	9.303
1995	5.245
2000	5.166
2005	3.376
2006	0.437
2007	3.549

Source: Climate Profile of India (2010), India Meteorological Department.

Figure- 2.10
Flood Affected Area during 1955-2007

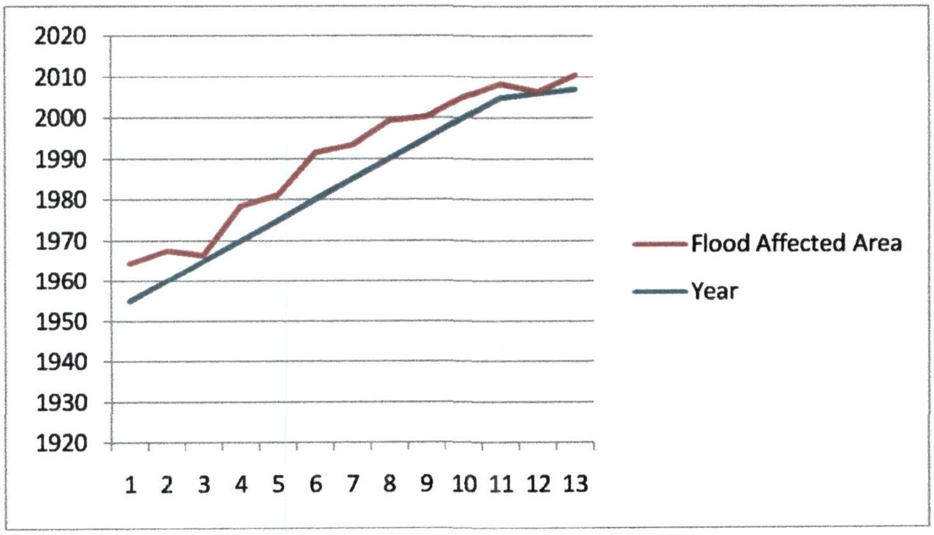


Table-2.6 shows flood affected area of the country with a interval of five years. According to the table, flood affected area in 1955 was 9.44 million hectares. After five years in 1960 it was 7.53 million hectares. In 1965 it was much less, only 1.46 million hectares. But again in 1970 it increases to 8.46 million hectares and then slightly goes down to 6.17 million hectares in 1985. But in 1980 it was the largest area affected by flood i.e. 11.46 million hectares. In 1985, 8.38 million hectares area was affected by floods which slightly increased to 9.303 million hectares in 1990. With the introduction of the flood prevention measures, the area affected by floods decreases to 5.245 mm in 1995, then to 5.166 mm in 2000 and much lesser in 2005 to 3.376 million hectares. In 2006 the flood affected area was 0.437 million hectares which increased to 3.549 million hectares in 2007.

The above explanation can be better understood with the help of line graph shown in above figure-2.10.

After the heavy floods in 1954, national policy on "Floods in the country" was set up in 1954 by government of India that provides measures for flood control and its protection. The central flood board was set up in 1954. Flood forecasting has been recognized most important reliable and cost effective non-structural measure for flood mitigation. India Meteorological Department (IMD) and Central Water Commission (CWC) are working in close co-ordination for issue of flood forecasts. IMD has ten flood meteorological offices (FMOs) and CWC has twenty flood forecasting divisions located in different flood prone river basins.

The failure of structural measures to prevent floods has been recognized, and several recent destructive floods on different continents have also contributed to the shift in approach. It has been clear that physical or structural protection measures such as domes, storage reservoirs, and embankments alone cannot completely protect against floods (Kundzewicz and Takeuchi, 1999). Although they are still necessary for flood protection, particularly in urban areas, modern flood response strategies should rely on integrated approach that includes all three types of measure: first, maintaining and updating structural flood protection; second, enhancing water storage capacity in watersheds using different means, and third, strengthening social mitigation measures such as land-use planning, forecast and warning system, community emergency planning, and household mitigation actions. The importance of these different types of measures is, of course, site specific and should be assessed in a regional context. If it is to be successfully implemented an integrated approach must consider the technical and land-use measures that are related to the social and political drivers of behaviour within societies (www.ecologyandsociety.org).

2.5 Drought

Drought is universally acknowledged a phenomenon associated with scarcity of water. It is a normal, recurrent feature of climate and is observed in all the climatic zones. It is still largely unpredictable and varies with regard to the time of occurrence, duration intensity, and extent of the area affected from year to year. It is a temporary condition caused by significantly less (deficient) rainfall for an extended period of time, usually during a season when substantial rainfall is normally expected over the area. The deficiency in the rainfall is measured relative to the long -period average (LPA) of rainfall over the area. The severity of the drought can also be aggravated by other climatic factors such as high temperature, high wind and low humidity. Though the number of deaths directly attributable to drought during 1963-1992 is quite less (3 percent) compared to that caused by floods (26 percent) and tropical cyclones (19 percent), yet the number of persons affected by drought (33 percent) is the highest amongst all the natural disasters (number of persons affected by floods and tropical cyclones being 3 percent and 20 percent respectively) and the significant damage caused by drought is 22 percent which is comparable to the corresponding values of floods (32 percent) and tropical cyclones (30 percent) (WMO, 1994).

India Meteorological Department (IMD) monitors meteorological and agricultural drought based on 'percentage of rainfall departure' and 'aridity anomaly index' respectively.

Meteorological drought over an area is defined as a situation when the monsoon seasonal (June to September) rainfall over the area is less than 75 percent of its long-term average value. It is further classified as 'moderate drought', if the rainfall deficit is 26-50 percent and 'severe drought' when the deficit exceeds 50 percent of the normal. Further, a year is considered as a 'drought year' when the area affected by moderate and severe drought either individually or together is 20-40 percent of the total area of the country and seasonal rainfall deficiency during southwest monsoon season for the country as a whole is at least 10 percent or more. When the spatial coverage of drought is more than 40 percent then it is called as all India severe drought year. Based on the index of percentage departure of rainfall from normal, IMD has delineated sub-division wise drought since 1875 and frequency of moderate and severe drought and occurrences of probabilities of drought years during 1875-2010 have been presented in Table-2.7.

Table-2.7
Sub-Division Wise Frequencies of Moderate and Severe Drought during 1875-2010 and Probabilities of Drought Years

S. No.	Name of Sub-Division	Moderate	Severe	Total	Drought Probabilities (Total) in Percent
1	Andaman & Nicobar Islands	17	0	17	13
2	Arunachal Pradesh	7	1	8	6
3	Assam & Meghalaya	5	0	5	4
4	Nagaland, Manipur, Mizoram & Tripura	12	0	12	9
5	Sub-Himalayan West Bengal	7	0	7	5
6	Gangetic West Bengal	2	0	2	1
7	Orissa	5	0	5	4
8	Bihar	12	0	12	9
9	Jharkhand	6	0	6	4
10	East Uttar Pradesh	13	1	14	10
11	West Uttar Pradesh	13	1	14	10
12	Uttarakhand	16	2	18	13
13	Haryana, Delhi & Chandigarh	21	4	25	19
14	Punjab	20	4	24	18
15	Himachal Pradesh	20	3	23	17
16	Jammu & Kashmir	21	6	27	20
17	West Rajasthan	22	12	34	25
18	East Rajasthan	18	5	23	17
19	West Madhya Pradesh	14	0	14	10
20	East Madhya Pradesh (including Chhattisgarh)	12	0	12	9
21	Gujarat Region	17	11	28	21
22	Saurashtra & Kutch	16	15	31	23
23	Konkan & Goa	9	0	9	7
24	Madhya Maharashtra	7	1	9	7
25	Marathwada	17	1	18	13
26	Vidarbha	16	0	17	13
27	Coastal Andhra Pradesh	13	0	13	10
28	Telangana	18	2	18	13
29	Rayalaseema	20	0	22	16
30	Tamil Nadu & Pondicherry	12	0	12	9
31	Coastal Karnataka	5	0	5	4
32	North Interior Karnataka	10	0	10	7
33	South Interior Karnakata	9	0	9	7
34	Kerala	10	0	10	7
35	Lakshadweep	10	3	13	10

Source: Climate Profile of India (2010), India Meteorological Department.

As given in table-2.7, it is observed that arid west viz. West Rajasthan (34 cases) and Saurashtra and Kutch (31 cases), have the highest occurrences of drought. The adjoining Gujarat Region which mostly belongs to semi-arid climate also experiences high incidences of drought (28 cases). Other areas recording large incidences of drought are Haryana, Delhi & Chandigarh (25 cases), Punjab (24 cases), Himachal Pradesh (23 cases) and East Rajasthan (23 cases) in northwest India and Rayalaseema (22 cases) in southern peninsula. The per-humid and humid areas of the east and north-east India viz. Arunachal Pradesh (8 cases), Assam & Meghalaya (5 cases), Orissa (5 cases), Gangetic West Bengal (2 cases) and Jharkhand (6 cases), for obvious reasons, have the lowest occurrences of drought.

Majority of the districts in the north west part of the country consisting of Rajasthan, Gujarat, Jammu & Kashmir, Punjab, Haryana have drought probabilities of more than or equal to 20 percent. The probabilities decrease as moving eastwards from northwest India to northeast India. Over northwest India, most of the districts have probabilities of less than 10 percent. Over the peninsula, many of the interior districts have probability of more than equal to 20 percent. Districts along the west coast show less than 10 percent probability. The probability for severe drought is also highest in the districts from northwest India. Some isolated districts over various other parts of the country shows probability for severe drought of more than 5 percent.

The highest probabilities of drought of various intensities are not distributed only over the arid or semi-arid regions. It can be seen that for all the districts, the probability for the moderate drought is more than 10 percent and over majority of the districts the probability of the severe drought is more than 5 percent. The districts with probabilities more than 15 percent, though spread in almost all parts of the country, are somewhat concentrated in north-western part of the country (consisting of Gujarat, Rajasthan, Punjab, Haryana, Chandigarh, Delhi and Jammu & Kashmir) and eastern part of the Peninsula (Gangetic West Bengal, Orissa, Vidarbha, Marathwada, Andhra Pradesh, Interior Karnataka and Tamil Nadu).

The trend analysis of district-wise showed significant decreasing trends over many districts in Uttaranchal, Kerala and in the subdivisions from east central India and such as east Madhya Pradesh, Vidarbha, Chhattisgarh, Jharkhand, Bihar etc., and significant increasing trend was observed over several districts, from Konkan region, Karnataka, west Madhya Pradesh, Andhra Pradesh, Punjab and West Uttar Pradesh. Some districts from Kerala and Chhattisgarh showed decreasing trends in SPI series and relatively high probability for drought occurrences of moderate and above intensity.

Based on the probabilities of occurrence of drought (percentage), the entire country has been divided into chronically drought prone area (probability of occurrence of drought more than 20 percent), frequently drought prone area (probability of occurrence of drought 10-20 percent) and least drought prone area (probability of occurrence of drought less than 10 percent). West Rajasthan and the entire Gujarat State fall in the category of chronically drought prone area. Therefore, these areas deserve special attention for drought proofing like evolving crop varieties resistant to moisture stress, better water management, effective land management etc. East Uttar Pradesh, Uttarakhand, Haryana, Punjab, Himachal Pradesh, East Rajasthan, West Madhya Pradesh, Marathwada, Vidarbha, Telangana, Coastal Andhra Pradesh and Rayalaseema fell in the category of frequently drought prone areas which can expect drought once in 6-10 years. These areas generally belong to sub-humid climate zone (IMD Met. Monograph No. 21/2005).

Drought protection measures range from management of water supplies to demand management of scarce freshwater resources. Using groundwater rather than the more traditional surface reservoirs can be quite efficient despite the higher pumping costs. This is mainly because there are very high evaporation losses from surface reservoirs. Some relatively new measures such as the recycling of water, e.g. the use of treated municipal waste water for irrigation, and the desalinization of seawater are also increasingly applied. Measures such as diversification, non-farm related livelihoods, change in the economic structures of households and regions, and migration are of basic importance to drought vulnerability and may become even more important under climate change (www.ecologyandsociety.org).

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Chapter-3

Climate and Foodgrains Production

CLIMATE AND FOODGRAINS PRODUCTION

3.1 Introduction

Agricultural production has two components foodgrains and non-foodgrains. Foodgrains contribute approximately two-thirds of total agricultural production. In the Index Number of Agricultural Production (triennium ending 1981-82 = 100), the weights assigned to foodgrains and non-foodgrains are 62.1 and 37.1 respectively. The most important component in the foodgrains category is rice (weight 29.7) followed by wheat (weight 14.5) (Agricultural Production and Productivity Trends 1950-51 to 2010-11).

As far as foodgrains output is concerned, the total production increased from 50.8 million tonnes in 1950-51 to 187.0 million tonnes in the Eighth Plan (annual average) and further to 202.9 million tonnes in the Ninth Plan (annual average). However, because of drought conditions in the first year of the Tenth Plan 2002-2003, the foodgrains output declined to 147.8 million tonnes but again rose to 213.2 million tonnes in 2003-04. The foodgrains output in the Tenth Plan (annual average) was 202.2 million tonnes – even less than the annual average recorded in the Ninth Plan. However, the last year of the Tenth Plan, 2006-07, registered an impressive foodgrains output of 217.28 million tonnes. This further rose to 234.4 million tonnes in 2008-09 but fell to 218.2 million tonnes in 2009-10. According to the Fourth Advance Estimates for the year 2010-11 the total foodgrains production rose to the record production of 257.44 million tonnes.

Major Indian cropping seasons are Kharif, Rabi and Zaid. Kharif crops are sown at the beginning of the south-west monsoon and harvested at the end of the south-west monsoon. These crops are water intensive in nature, thus fluctuations in weather bear a significant impact on its outcome. The sowing season starts from May and is completed by the month of July. The harvesting of these crops occurs during September-October. Rabi crops need relatively cool climate during the period of growth but warm climate during germination period and maturity phase. October to December is the sowing time and harvesting season starts from February and continues till April. Besides the Kharif and Rabi crops another major cropping season is Zaid in which crops are grown throughout the year deploying artificial irrigation system.

In all these three cropping seasons keeping all the agricultural inputs constant, climate is the most important in which temperature and rainfall are two most important determinants. Since the data is not available at all India level about temperature on yearly basis, presently we will consider the rainfall as the determinant of climate. In this chapter we will see the relationship between change in pattern of rainfall and agricultural production.

3.2 Rabi Crops and Climate

Rabi crops refer to those agricultural plants which are sown in winter and harvested in the spring. Rabi crops are grown between the months of November to April. The water that has percolated in the ground during the rains is main source of water for these crops. Rabi crops require irrigation. These crops are taken after the departure of monsoon rains. The seeds are sown after the rains have gone and harvesting begins in April/May.

The Rabi season starts with the onset of north-west monsoon in October. Many crops are cultivated in Rabi season. Major Rabi crop is wheat in India followed by barely, mustard, sesame and peas. They are harvested early because of their shorter maturity period. Because of this Indian markets are flooded with Green Peas from January to March. The other items of Rabi crops are Gram, Pea, Linseed, Jowar, Maize, Peas, etc.

3.2.1 Wheat

Wheat is the most important foodgrain of India next to rice and is the staple food of millions of Indians, particularly in the northern and north-western parts of the country. India is the fourth largest producer of wheat in the world after Russia, the USA and China and accounts for 8.7 percent of the world's total production of wheat. Wheat is a rabi crop which is sown in the beginning of winter and is harvested in the beginning of summer. The time of sowing and harvesting differs in different regions due to climatic variations.

Weather conditions that is comfortable for humans is also good for wheat. Wheat needs 12 to 15 inches (31 to 38 centimetres) of water to produce a good crop. Wheat thrives well in areas receiving an annual rainfall of about 75 cm. Annual rainfall of 100 cm is the highest limit of wheat cultivation. In area of less than 50 cm annual rainfall, irrigation is necessary for its successful growth. It grows best when temperatures are warm, from 21^0 to 24^0C but not too hot. Wheat also needs a lot of sunshine, especially when the grains are filling. Areas with low humidity are better since many wheat diseases thrives in damp weather.

Table-3.1

Production of Wheat and All India Rainfall Distribution from 2000-01 to 2011-12

Year	Wheat Production (in million tonnes)	Rainfall (Oct – Dec) (in millimetres)		Rainfall (Jan – Feb) (in millimetres)	
		Actual	Percentage Departure	Actual	Percentage Departure
2000-01	69.68	64.1	-47.3	16.2	-61.6
2001-02	72.77	137.7	13.1	35.0	-15.0
2002-03	65.76	83.4	-32.6	53.2	38.9
2003-04	72.15	134.6	7.7	34.5	-12.0
2004-05	68.64	111.8	-11.1	69.8	59.0
2005-06	69.35	138.4	10.0	27.8	-37.0
2006-07	75.81	99.3	-21.1	34.3	-21.7
2007-08	78.57	85.4	-32.2	42.6	-1.4
2008-09	80.68	87.2	-30.7	23.6	-46.1
2009-10	80.80	135.5	7.6	24.6	-43.8
2010-11	86.87	153.2	21.3	31.9	-22.0
2011-12	93.90	65.7	-48.3	38.8	-5.1

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.1

Actual Rainfall and Production of Wheat from 2000-01 to 2011-12

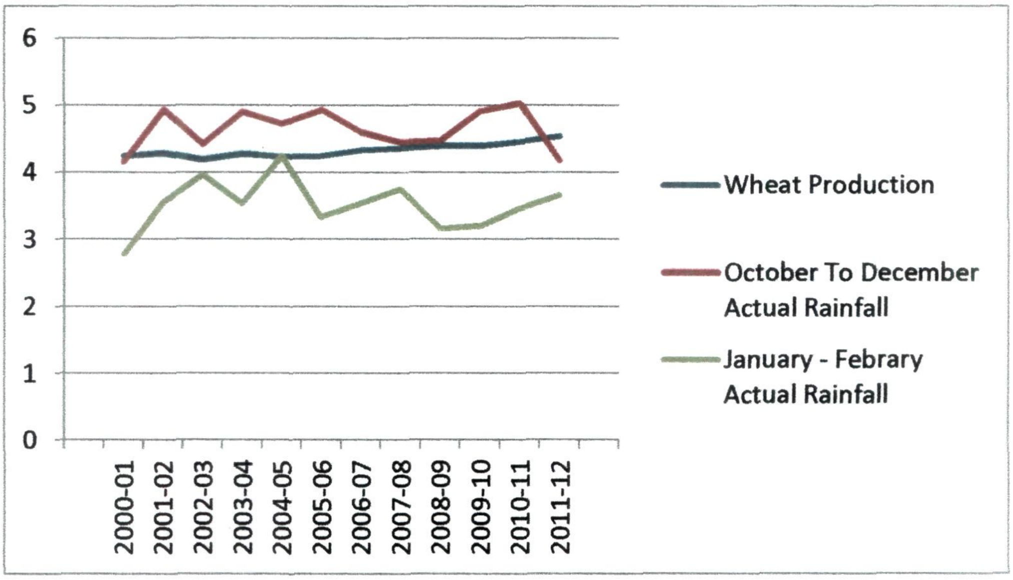


Table-3.1 shows the production of Wheat (in million tonnes) and all India actual rainfall distribution (in millimeters) for the months October to December and January-February during 2000-01 to 2011-12.

The production of Wheat in 2000-01 was 69.68 million tonnes and the actual rainfall for growing and harvesting seasons was 64.1 mm (October to December) and 16.2 mm (January - February) respectively. When rainfall increases to 137.7 mm and 35 mm respectively the production also increases to 72.77 million tonnes in 2001-02. Again in 2002-03 when actual rainfall for October to December declines to 83.4 mm, production of Wheat also declines to 65.76 million tonnes. This pattern continues till 2005-06. But in 2006-07, when actual rainfall for growing season declines from 138.4 mm to 99.3 mm, production increase from 69.35 to 75.81 million tonnes. This may have been supported by an increase in rainfall during the harvesting season from 27.8 mm to 34.3 mm. The same situation was seen in 2007-08 also. But again in 2008-09 when growing season rainfall increases to 87.2 mm, production of Wheat increases to 80.68 million tonnes irrespective of a fall in rainfall during harvesting season which declines to 23.6 mm.

In 2009-10 production of Wheat increases to 80.80 million tonnes supported by a good rainfall for both the seasons which increases to 135.5 mm and 24.6 mm. Similarly in 2010-11 the rainfall increases to 153.2 mm and 31.9 mm in both the seasons respectively and so does the production which increases to 86.87 million tonnes. But in 2011-12 even when the post – monsoon rainfall declines to 65.7 mm, production increases to 93.90 million tonnes with increase in the winter rainfall to 38.8 mm.

This entire relationship between rainfall and production can be better explained with the help of line graph. Figure-3.1 shows the production of wheat and actual rainfall for both the seasons through three different lines on one graph.

3.2.2 Jowar

Jowar is the third most important food crop next to rice and wheat with respect to both area and production. It is grown in both Rabi and Kharif season. As a Rabi crop it can be grown in areas where the mean monthly temperature does not fall below 16^0C. It requires more than 30 cm rainfall during the growing period and does not grow where the rainfall exceeds 100 cm.

Jowar is par excellence a rainfed crop of dry farming areas where irrigation is not used. Both excessive moisture and prolonged droughts are harmful for its proper growth. Most of the crop is grown in plain areas but it can also be raised on gentle slopes upto 1200 meters height.

Table-3.2

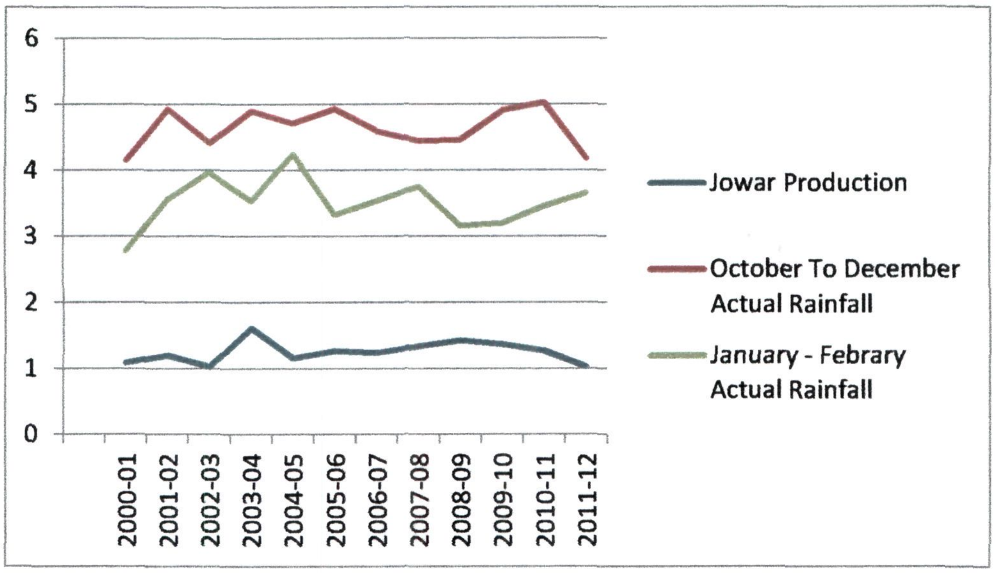
Production of Jowar and All India Rainfall Distribution from 2000-01 to 2011-12

Year	Jowar Production (in million tonnes)	Rainfall (Oct – Dec) (in millimetres)		Rainfall (Jan – Feb) (in millimetres)	
		Actual	Percentage Departure	Actual	Percentage Departure
2000-01	2.97	64.1	-47.3	16.2	-61.6
2001-02	3.33	137.7	13.1	35.0	-15.0
2002-03	2.79	83.4	-32.6	53.2	38.9
2003-04	1.84	134.6	77	34.5	-12.9
2004-05	3.20	111.8	-11.1	69.8	59.0
2005-06	3.56	138.4	10.0	27.8	-37.0
2006-07	3.44	99.3	-21.1	34.3	-21.7
2007-08	3.82	85.4	-32.2	42.6	-1.4
2008-09	4.19	87.2	-30.7	23.6	-46.1
2009-10	3.94	135.5	7.6	24.6	-43.8
2010-11	3.56	153.2	21.3	31.9	-22.0
2011-12	2.79	65.7	-48.3	38.8	-5.1

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.2

Actual Rainfall and Production of Jowar from 2000-01 to 2011-12



The data about the production of Jowar (in million tonnes) in Rabi Season and the rainfall during growing and harvesting seasons is given in table 3.2.

As given in the above table, the production of Jowar in 2000-01 was 2.97 million tonnes, and the rainfall for the months of October to December and January-February were 64.1 mm (actual), -47.3 (percentage departure) and 16.2 mm (actual), 61.6 (percentage departure) respectively. When actual rainfall for the months of October to December increased, production also increases in 2001-02 and in 2002-03 production decreases with decrease in rainfall. But in 2003-04, even when the actual rainfall increase to 134.6 mm production decreases to 1.84 million tonnes, because the rainfall of January-February decreases from 53.2 mm to 34.5 mm. The same situation was in 2004-05. Again in 2005-06 the production of Jowar was once again affected by post-monsoon rainfall i.e. with an increase in actual rainfall to 138.4 mm, production also increases to 3.56 million tonnes. Similarly in 2006-07, when rainfall decreases, production also decreases to 3.44 million tonnes.

Thus during the entire study period it was seen that the production of Jowar was affected sometimes by the rainfall of growing season and sometimes by the harvesting season. In 2011-12, when growing season rainfall declines from 153.2 mm to 65.7 mm, production of Jowar also decreases from 3.56 million tonnes to 2.79 million tonnes, although the harvesting season rainfall increases from 31.9 mm to 38.8 mm.

Figure-3.2 shows the line graph of the production of Jowar and the rainfall distribution. Explanation of the table can be easily seen through this graph. The three lines clearly shows the effect of rainfall on the production of Jowar.

3.2.3 Maize

Maize is an inferior grain which is used both as food and fodder. Its grain provides food and is used for obtaining starch and glucose. Its stalk is fed to cattle. Maize in mainly a Kharif crop but in Tamil Nadu it is a rabi crop and is sown a few weeks before the onset of winter rainy season in September and October. Maize can be grown under varied climatic and soil conditions which are explained in Kharif section of this chapter.

Table-3.3

Production of Maize and All India Rainfall Distribution from 2000-01 to 2011-12

Year	Maize Production (in million tonnes)	Rainfall (Oct – Dec) (in millimetres)		Rainfall (Jan – Feb) (in millimetres)	
		Actual	Percentage Departure	Actual	Percentage Departure
2000-01	1.82	64.1	-47.3	16.2	-61.6
2001-02	1.91	137.7	13.1	35.0	-15.0
2002-03	1.88	83.4	-32.6	53.2	38.9
2003-04	2.25	134.6	7.7	34.5	-12.0
2004-05	2.70	111.8	-11.1	69.8	59.0
2005-06	2.55	138.4	10.0	27.8	-37.0
2006-07	3.54	99.3	-21.1	34.3	-21.7
2007-08	3.85	85.4	-32.2	42.6	-1.4
2008-09	5.61	87.2	-30.7	23.6	-46.1
2009-10	4.43	135.5	7.6	24.6	-43.8
2010-11	5.09	153.2	21.3	31.9	-22.0
2011-12	5.35	65.7	-48.3	38.8	-5.1

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.3

Actual Rainfall and Production of Maize from 2000-01 to 2011-12

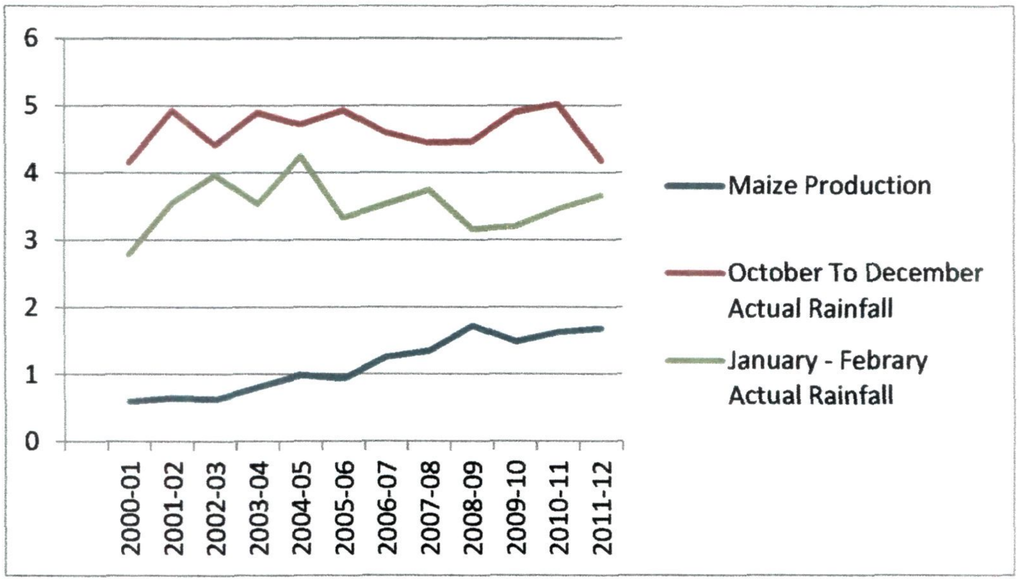


Table-3.3 shows the production of Maize (in million tonnes) which is affected by rainfall during Rabi season. Rainfall was recorded for both post-monsoon and winter season and is given in millimeters.

According to the table the production of Maize in 2000-01 was 1.82 million tonnes and the rainfall was 64.1 mm and 16.2 mm for the post-monsoon and winter season respectively. From 2001-02 to 2003-04, the production of Maize was directly affected by the actual rainfall during post-monsoon season, i.e. when rainfall increases production increases and vice-versa. In 2004-05 the actual rainfall of winter season increases from 34.5 mm to 69.8 mm and therefore the production of Maize increases from 2.25 to 2.70 million tonnes irrespective of the decrease in rainfall of post-monsoon season from 134.6 mm to 111.8 mm. Similarly in the next three years, the production is directly related to the winter rainfall i.e. till 2007-08 when winter rainfall increases, production increases and vice-versa. In 2008-09, once again when rainfall in post-monsoon season increases from 85.4 mm to 87.2 mm, production increases from 3.85 to 5.61 million tonnes despite the fact that the rainfall of winter season decreases from 42.6 mm to 23.6 mm.

In 2009-10, it was seen that instead of increase in the rainfall of both the season, production declines. But in 2010-11, when the rainfall of both the season increases, production of Maize also increases. In 2011-12, the rainfall of winter season increases from 31.9 mm to 38.8 mm and so the production increases from 5.09 to 5.35 million tonnes. But the rainfall of post-monsoon season declines from 153.2 mm to 65.7 mm.

Figure-3.3 shows the production of Maize from 2000-01 to 2011-12. On the same graph, the actual rainfall during post-monsoon and winter season is shown through two different lines. The line graph clearly shows that the production of Maize is affected by the post-monsoon and winter rainfall.

3.2.4 Barley

Barley is considered as an inferior grain. It does not tolerate high heat and high humidity and thrives well in areas where the temperature is 10^0 - 15^0C for about three months in a year and the rainfall varies from 75 cm to 100 cm. It is grown as a rabi crop in the great plains and valleys of the western Himalayas. It can be grown upto an altitude of 13,00 meters as in Uttaranchal. High clay and alluvial soils are best suited for its cultivation.

Table-3.4

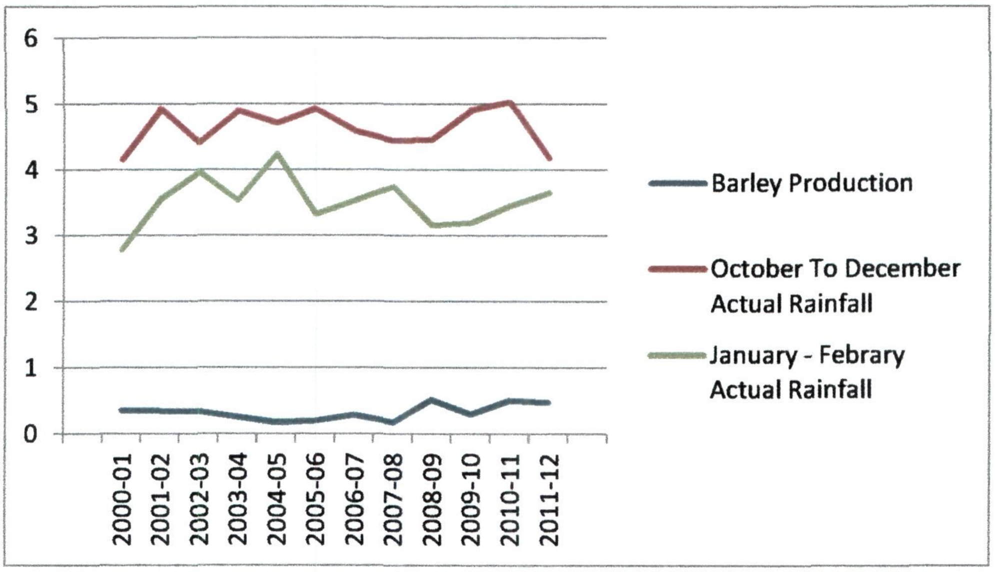
Production of Barley and All India Rainfall Distribution from 2000-01 to 2011-12

Year	Barley Production (in million tonnes)	Rainfall (Oct – Dec) (in millimetres)		Rainfall (Jan – Feb) (in millimetres)	
		Actual	Percentage Departure	Actual	Percentage Departure
2000-01	1.43	64.1	-47.3	16.2	-61.6
2001-02	1.42	137.7	13.1	35.0	-15.0
2002-03	1.41	83.4	-32.6	53.2	38.9
2003-04	1.30	134.6	7.7	34.5	-12.0
2004-05	1.20	111.8	-11.1	69.8	59.0
2005-06	1.22	138.4	10.0	27.8	-37.0
2006-07	1.33	99.3	-21.1	34.3	-21.7
2007-08	1.20	85.4	-32.2	42.6	-1.4
2008-09	1.69	87.2	-30.7	23.6	-46.1
2009-10	1.35	135.5	7.6	24.6	-43.8
2010-11	1.66	153.2	21.3	31.9	-22.0
2011-12	1.61	65.7	-48.3	38.8	-5.1

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.4

Actual Rainfall and Production of Barley from 2000-01 to 2011-12



The information about the production of Barley (in million tonnes) which is a Rabi crop and all India rainfall distribution, actual and departure (in millimeter) for the growing and harvesting season is given in table 3.4.

It can be seen from the table that the production of Barley in 2000-01 was 1.43 million tonnes, and the actual rainfall for the growing and harvesting season was 64.1 mm and 16.1 mm respectively. In 2001-02, the rainfall of both the season increases but the production of Barely decreases by 0.01 million tonnes. In 2002-03, the rainfall of harvesting season increases but of growing season declines and so does the production declines again by 0.01 million tonnes. The same relation was seen in the remaining years also. If in a year the production was affected by growing season's rainfall, then it was affected by the harvesting season's rainfall in the other year.

In 2009-10, the rainfall of both the season increases, i.e., in growing season from 87.2 mm to 135.5 mm and in harvesting season from 23.6 mm to 24.6 mm, but the production of Barley declines from 1.69 million tonnes to 1.35 million tonnes. Again the direct relationship can be seen in 2010-11. Both the rainfall increases to 153.2 mm and 31.9 mm respectively and thus the production increases to 1.66 million tonnes. But in 2011-12, only the harvesting season's rainfall increases to 38.8 mm, growing season's rainfall decreases to 65.7 mm and also the production declines to 1.61 million tonnes.

The effect of growing and harvesting season's rainfall on the production of Barley can also be explained with the help of line graph shown in figure-3.4. The three different lines on the same graph shows the production of Barley, actual rainfall of growing season i.e. October to December and actual rainfall during harvesting season i.e. January-February.

3.2.5 Coarse Cereals

Coarse Cereals have been traditionally the main components of the food basket of the poor in India. Predominantly grown in the resource fragile agro-climatic regions of the country, these crops include jowar, ragi, bajra, harka and other small millets. These are cultivated more in Karnataka, Maharashtra, Tamil Nadu, Madhya Pradesh, Rajasthan and Gujarat. The area under coarse cereals has been declining in most of the regions growing these crops and as a result the crop group is relegated as 'inferior crops'. These crops are grown by the small and marginal farmers residing in such regions having repercussion of changes upon their household economy.

Table-3.5

Production of Coarse Cereals and All India Rainfall Distribution from 2000-01 to 2011-12

Year	Coarse Cereals Production (in million tonnes)	Rainfall (Oct – Dec) (in millimetres)		Rainfall (Jan – Feb) (in millimetres)	
		Actual	Percentage Departure	Actual	Percentage Departure
2000-01	6.22	64.1	-47.3	16.2	-61.6
2001-02	6.66	137.7	13.1	35.0	-15.0
2002-03	6.08	83.4	-32.6	53.2	38.9
2003-04	5.39	134.6	7.7	34.5	-12.0
2004-05	7.10	111.8	-11.1	69.8	59.0
2005-06	7.33	138.4	10.0	27.8	-37.0
2006-07	8.31	99.3	-21.1	34.3	-21.7
2007-08	8.87	85.4	-32.2	42.6	-1.4
2008-09	11.49	87.2	-30.7	23.6	-46.1
2009-10	9.72	135.5	7.6	24.6	-43.8
2010-11	10.32	153.2	21.3	31.9	-22.0
2011-12	9.75	65.7	-48.3	38.8	-5.1

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.5

Actual Rainfall and Production of Coarse Cereals from 2000-01 to 2011-12

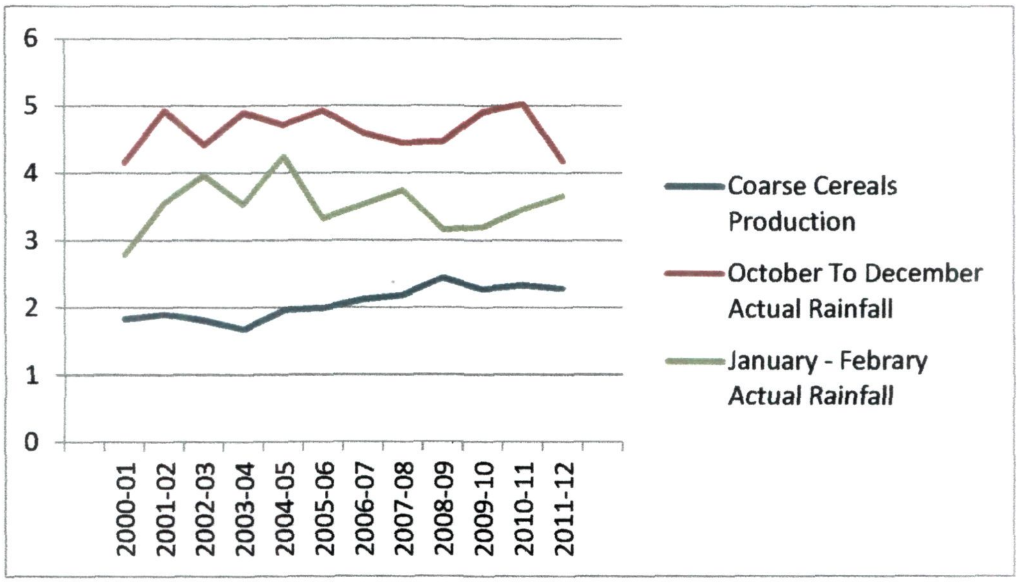


Table-3.5 shows the production of Coarse Cereals (in million tonnes) and the actual rainfall (in millimeters) for the months of October to December and January – February during 2000-01 to 2011-12 in Rabi season.

The production of Coarse Cereals was 6.22 million tonnes in 2000-01 and the rainfall for the months of October to December and January – February was 64.1 mm and 16.2 mm respectively. In 2001-02, the rainfall during both the periods increases and hence the production also increases to 6.66 million tonnes. In 2002-03, the rainfall of October-December declines to 83.4 mm and thus the production declines to 6.08 million tonnes. In 2003-04, the rainfall of January-February declines from 53.2 to 34.5 mm and consequently the production declines to 5.39 million tonnes. In 2004-05 when rainfall increases to 69.8 mm, production increases to 7.10 million tonnes. In 2005-06, the rainfall of January-February declines to 27.8 mm, but of October to December increases to 138.4 mm and therefore the production increases to 7.33 million tonnes. In 2006-07, the rainfall during January-February increases to 34.3 mm and during October to December declines to 99.3 mm, and the production increases to 8.31 million tonnes. In 2011-2012, the production of Coarse Cereals declined to 9.75 million tonnes because of a comparatively higher decline in the rainfall during October to December than the increase in the rainfall during January to February.

It can be seen that during the entire study period the production of coarse cereals was sometimes affected by the rainfall of growing season i.e. October to December and sometimes by the rainfall during harvesting season i.e. January-February.

Figure-3.5 is the line graph which shows the production of Coarse Cereals and actual rainfall for the month of October to December and January – February. It is clear from the graph that the production of Coarse Cereals was sometimes affected by rainfall during October to December and sometimes by the rainfall during January-February during twelve different years.

3.2.6 Total Pulses

Pulses are unique crops as they have in-built mechanism to fix atmosphere nitrogen in their root nodules. They are also rich in protein and fit well in various cropping system. India is a rare country which grows such a variety of pulse crops which none of the countries in the world grows.

Gram is the most important of all the pulses and accounts for 37 percent of the production and 28.28 percent of the total area of pulses in India. It is a rabi crop, which is sown between September and November and is harvested between February and April. It is cultivated as pure or mixed with wheat, barley, linseed or mustard. It can be grown in a wide range of climatic conditions but it prefers mild cool and comparatively dry climate with 20^0C - 25^0C temperature and 40-50 cm rainfall. It grows well on loamy soils.

Table-3.6

Production of Total Pulses and All India Rainfall Distribution from 2000-01 to 2011-12

Year	Total Pulses Production (in million tonnes)	Rainfall (Oct – Dec) (in millimetres)		Rainfall (Jan – Feb) (in millimetres)	
		Actual	Percentage Departure	Actual	Percentage Departure
2000-01	6.62	64.1	-47.3	16.2	-61.6
2001-02	8.53	137.7	13.1	35.0	-15.0
2002-03	6.98	83.4	-32.6	53.2	38.9
2003-04	8.74	134.6	7.7	34.5	-12.0
2004-05	8.41	111.8	-11.1	69.8	59.0
2005-06	8.52	138.4	10.0	27.8	-37.0
2006-07	9.40	99.3	-21.1	34.3	-21.7
2007-08	8.36	85.4	-32.2	42.6	-1.4
2008-09	9.88	87.2	-30.7	23.6	-46.1
2009-10	10.46	135.5	7.6	24.6	-43.8
2010-11	11.12	153.2	21.3	31.9	-22.0
2011-12	11.05	65.7	-48.3	38.8	-5.1

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.6

Actual Rainfall and Production of Total Pulses from 2000-01 to 2011-12

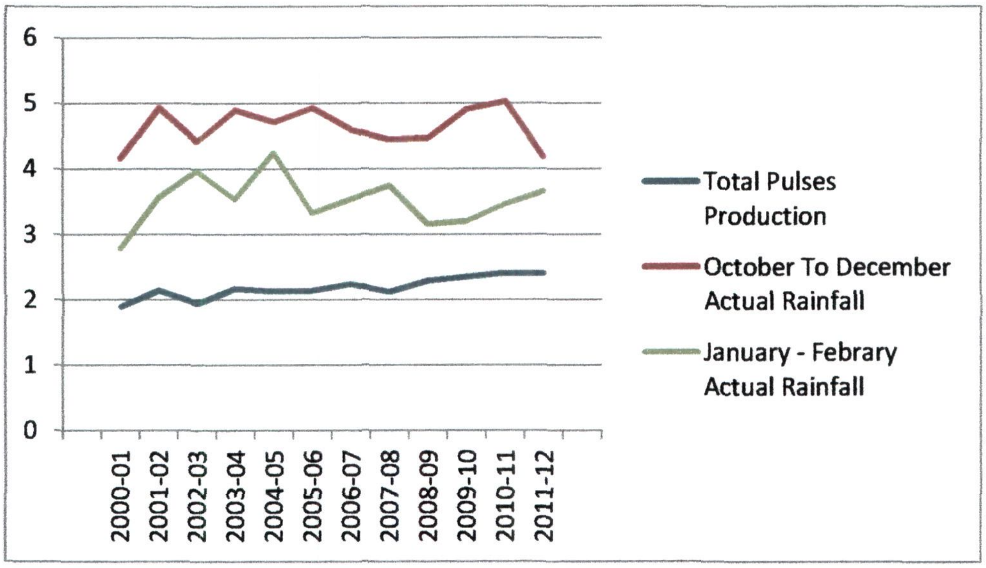


Table-3.6 shows the production of Total Pulses (in million tonnes) in Rabi season and the effect of post-monsoon and winter rainfall (in millimeters) on its production. These two seasons are respectively the growing and harvesting season of Rabi crops.

In 2000-01, the production of Total Pulses was 6.62 million tonnes and the rainfall in the growing and harvesting seasons of Rabi crops was 64.1 mm and 16.2 mm respectively. In 2001-02, the rainfall in both the seasons increases to 137.7 mm and 35 mm respectively and also the production increases to 8.53 million tonnes. Till 2005-06, the production of Total Pulses was directly dependent on the rainfall of growing season. That is, when rainfall increases production increases and vice-versa. But in 2006-07 instead of fall in rainfall of growing season, production of Total Pulses increases from 8.52 to 9.4 million tonnes with an increase in the rainfall of harvesting season.

In 2007-08, once again the production was directly affected by the growing season's rainfall and the same continues till 2011-12. In 2009-10 and 2010-11, the rainfall in both the seasons increases and so does the production increases in both the years. But in 2011-12, only the rainfall of harvesting season increases from 31.9 mm to 38.8 mm, the rainfall of growing season decreases from 153.2 mm to 65.7 mm and thus the production of Total Pulses declines from 11.12 million tonnes to 11.05 million tonnes.

As explained above, that the production of Total Pulses was directly dependent on the rainfall of growing season from 2000-01 to 2005-06, which is clearly shown in the above figure. Figure-3.6 is the line graph of production of Total Pulses and actual rainfall during growing and harvesting seasons of Rabi crops. Except 2006-07, all the remaining years till 2011-12, production was directly affected by the rainfall during growing season.

3.2.7 Total Foodgrains

Total foodgrains of rabi season include Wheat, Jowar, Maize, Barley, Coarse Cereals, Gram, Urad, Moong etc. The growing conditions of these crops including temperature, rainfall, soil etc. are discussed previously.

Table-3.7

Production of Total Foodgrains and All India Rainfall Distribution from 2000-01 to 2011-12

Year	Total Foodgrains Production (in million tonnes)	Rainfall (Oct – Dec) (in millimetres)		Rainfall (Jan – Feb) (in millimetres)	
		Actual	Percentage Departure	Actual	Percentage Departure
2000-01	94.72	64.1	-47.3	16.2	-61.6
2001-02	100.78	137.7	13.1	35.0	-15.0
2002-03	87.55	83.4	-32.6	53.2	38.9
2003-04	96.19	134.6	7.7	34.5	-12.0
2004-05	95.05	111.8	-11.1	69.8	59.0
2005-06	98.73	138.4	10.0	27.8	-37.0
2006-07	106.71	99.3	-21.1	34.3	-21.7
2007-08	109.83	85.4	-32.2	42.6	-1.4
2008-09	116.33	87.2	-30.7	23.6	-46.1
2009-10	114.16	135.5	7.6	24.6	-43.8
2010-11	123.60	153.2	21.3	31.9	22.0
2011-12	127.50	65.7	-48.3	38.8	-5.1

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.7

Actual Rainfall and Production of Total Foodgrains from 2000-01 to 2011-12

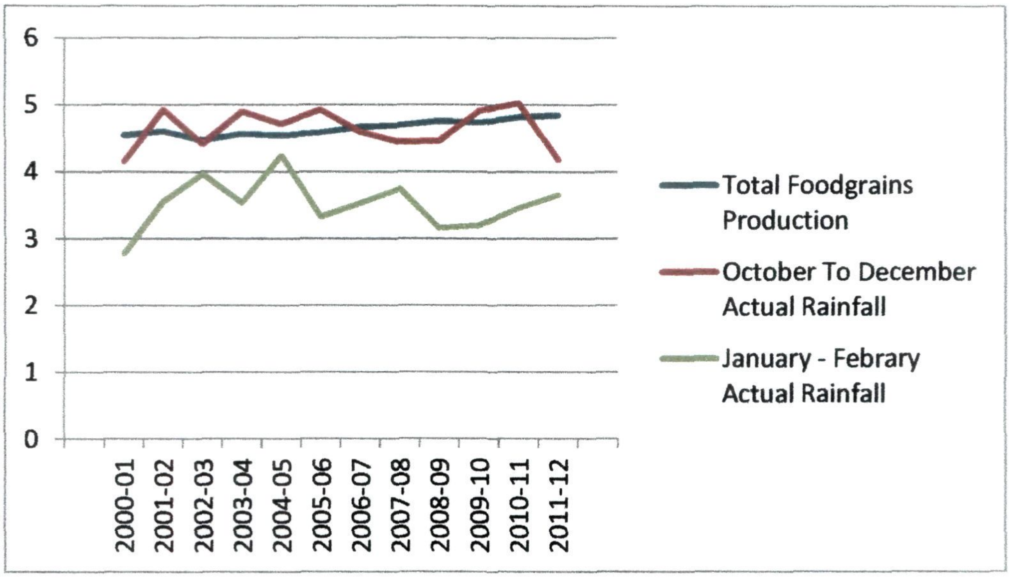


Table-3.7 shows the production of Total Foodgrains (in million tonnes) during Rabi season and all India rainfall distribution in growing season (October to December) and harvesting season (January - February) of Rabi Crops.

The table shows that the production of Total Foodgrains in 2000-01 was 94.72 million tonnes and the actual rainfall for growing season and harvesting season was 64.1 and 16.2 mm respectively. In 2001-02, the production increases to 100.78 million tonnes and so the rainfall of both the seasons increases to 137.7 mm and 35 mm respectively. From 2001-02 to 2005-06, the production of Total Foodgrains increases with an increase in the rainfall of growing season and vice-versa. But in 2006-07 and 2007-08 the production increases with an increase in rainfall of harvesting season irrespective of the decline in the rainfall of growing season. Again in 2008-09 production increases to 116.33 million tonnes with an increase in the actual rainfall of growing season to 87.2 mm. In 2009-10, although the rainfall of both the season increases to 135.5 mm and 24.6 mm respectively but the production decreases to 114.16 million tonnes. Again in 2010-11, when rainfall of both the season increases to 153.2 mm and 31.9 mm respectively, production of Total Foodgrains also increases to 123.60 million tonnes. In 2011-12, the production increases to 127.50 million tonnes with an increase in the rainfall of harvesting season to 38.8 mm and the rainfall of growing season fall to 65.7 mm.

Figure-3.7 is the line graph of the production of Total Foodgrains and actual rainfall during growing season (October to December) and harvesting season (January-February). The above explanation is clear through this graph. The graph clearly shows the ups and downs in the production of Total Foodgrains with respect to the rainfall distribution in the two seasons of Rabi crops.

3.3 Kharif Crops and Climate

Kharif crops refer to the planting, cultivation and harvesting of any domesticated plant sown in the rainy (monsoon) season on the Asian subcontinent. Such crops are planted for autumn harvest and may also be called the summer or monsoon crop in India and Pakistan.

Kharif crops are usually sown with the beginning of the first rains in June/July, during the south-west monsoon season. In India the Kharif season varies by crops and state, with Kharif starting at the earliest in May and ending at the latest in January, but is popularly considered to start in June and to end in October. As the Monsoon rains advance towards the north India the sowing dates accordingly vary and it is done in July in North Indian states.

Major Kharif crop is Rice followed by Millet. These crops are totally dependent on the quality of rain water as well as its timing. Too much, too little or at wrong time rain may waste the whole year's efforts. The other crops of Kharif season are Maize, Jowar, Bajra, Ragi, Sugarcane, Soyabean, Tea, Cotton etc.

3.3.1 Rice

Rice is the most important food crop of India covering about one-fourth of the total cropped area and providing food to about half of the Indian population. This is the staple food of the people living in the eastern and the southern parts of the country. There are about 10,000 varieties of rice in the world out of which about 4000 are grown in India.

Rice is a Kharif crop and is grown under varying conditions in India from 8^0 to 25^0N latitude and from sea level to about 2,500 meters altitude. It is a tropical plant and requires high heat and high humidity for its successful growth. The temperature should be fairly high at mean monthly 24^0C. It should be 20^0-22^0C at the time of sowing, 23^0-25^0C during growth and 25^0-30^0C at the harvesting time. The average annual rainfall, required by rice is 150 cm. In areas receiving less than 100 cm annual rainfall, rice can be grown with the help of irrigation and is done in Punjab, Haryana and western U.P. About 40 percent of rice crop in India is raised under irrigation.

Table-3.8

Production of Rice and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Rice Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	72.78	833.7	-7.6
2001-02	80.52	826.0	-8.3
2002-03	63.08	737.1	-19.2
2003-04	78.62	947.3	4.9
2004-05	72.23	779.6	-12.7
2005-06	78.27	879.3	-1.0
2006-07	80.17	886.6	-0.6
2007-08	82.66	936.9	5.0
2008-09	84.91	873.2	-2.1
2009-10	75.91	689.8	-22.7
2010-11	80.69	912.8	2.2
2011-12	91.53	899.9	1.4
2012-13	85.59	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.8

Actual Rainfall and Production of Rice from 2000-01 to 2012-13

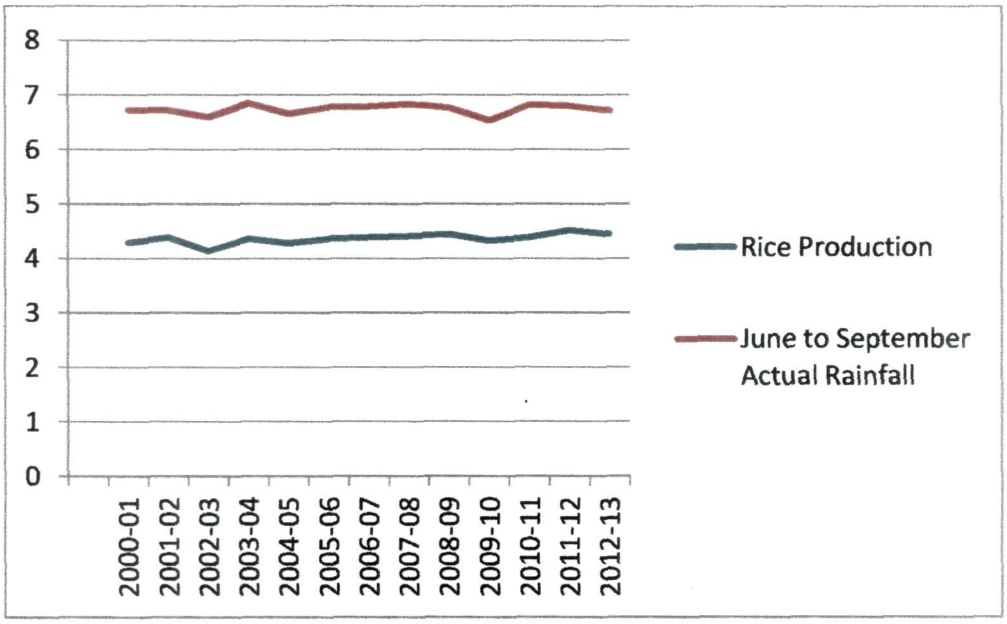


Table-3.8 shows the production of Rice (in million tonnes) in Kharif season with respect to the all India rainfall distribution (in millimeters) in the monsoon season i.e. for the months of June to September. We know that May, June, July and August are the growing months of Kharif crops, while September and October are the harvesting months. Thus, the Kharif crops are mostly affected by the monsoon rainfall.

The table shows that the production of Rice is 72.78 million tonnes in 2000-01 while the actual rainfall is 833.7 millimeters and percentage departure is -7.6. In 2001-02 the rainfall declines to 826 mm but the production of Rice increases to 80.52 million tonnes. Further, when rainfall declines to 737.1 mm, Rice production also declines to 63.08 million tonnes. This shows the direct effect of rainfall on production. The pattern continues till 2007-08, that is, when rainfall increases, production of Rice also increases and when rainfall decreases, the production of Rice also decreases. But in 2008-09, even when the rainfall decreases to 873.2 mm, the production increases to 84.91 million tonnes, and the percentage departure of rainfall is -2.1. In 2009-10 and 2010-11, again production depends directly on rainfall, when rainfall increases, production increases and vice versa. In 2011-12, rainfall decreases but production increases. In 2012-13 rainfall decreases from 899.9 mm to 819.5 mm and so as the production of Rice decreases from 91.53 million tonnes to 85.59 million tonnes.

This can also be explained with the help of line graph. Figure-3.8 shows the line graph of Rice production and actual rainfall distribution. Year is taken on the X-axis. The two lines shows Rice production and rainfall distribution separately. It is clear from the graph when rainfall decreases production increases in 2001-02 and when rainfall decreases production also decreases in 2002-03. The same variations are seen in the graph. Sometimes production is directly affected by rainfall and sometimes indirectly.

3.3.2 Jowar

Next to rice and wheat Jowar is the third most important food crop both with respect to area and production. Jowar is grown both as Kharif as well as Rabi crop. As a Kharif crop, it grows well in areas having mean monthly temperature of 26^0C to 33^0C. Jowar has suffered severely at the hands of other favoured crops. The area under jowar has been fluctuating, but the general trend has been towards its reduction.

Table-3.9

Production of Jowar and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Jowar Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	4.56	833.7	-7.6
2001-02	4.23	826.0	-8.3
2002-03	4.22	737.1	-19.2
2003-04	4.84	947.3	4.9
2004-05	4.04	779.6	-12.7
2005-06	4.07	879.3	-1.0
2006-07	3.71	886.6	-0.6
2007-08	4.11	936.9	5.0
2008-09	3.05	873.2	-2.1
2009-10	2.76	639.8	-22.7
2010-11	3.44	912.8	2.2
2011-12	3.24	899.9	1.4
2012-13	2.63	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.9

Actual Rainfall and Production of Jowar from 2000-01 to 2012-13

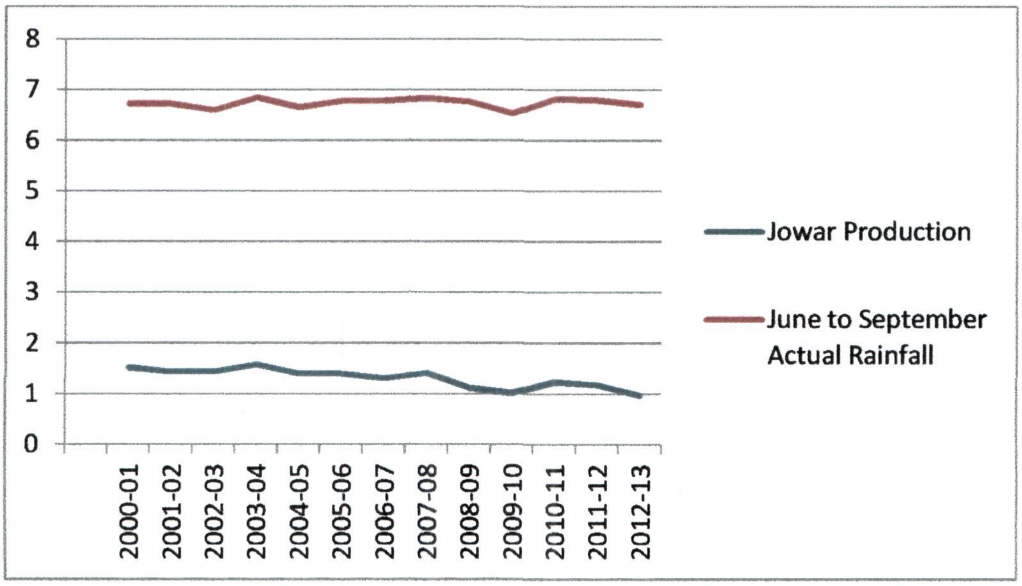


Table-3.9 shows the production of Jowar in Kharif season and all India distribution of rainfall, actual and percentage departure, for the monsoon season. Production is given in million tonnes and the rainfall in millimeters.

According to the table, in 2000-01, the production of Jowar was 4.56 million tonnes and rainfall, actual and percentage departure, was 833.7 mm and -7.6 respectively. When rainfall declines to 826 mm (actual) the production of Jowar also declines to 4.23 million tonnes. Again in 2001-02, when rainfall decreases to 737.1 mm, the Jowar production also decreases to 4.22 million tonnes. The same pattern continues in the entire table. This shows that the production of Jowar is directly affected by the actual rainfall for the months June, July, August and September. In 2011-12, the rainfall was 899.9 mm and the production was 3.24 million tonnes. When rainfall declines to 819.5 mm the production also declines to 2.63 million tonnes.

This relationship of the production of Jowar and actual rainfall can also be explained with the help of graph. Figure-3.9 shows the line graph of production of Jowar and actual rainfall in different years. The ups and downs of the two lines shows the direct relationship between the Jowar production and actual rainfall.

3.3.3 Bajra

Bajra is the second most important millet which is used as food in drier parts of the country. It is also widely used as fodder as its stalks are fed to cattle. In certain areas it is used for thatching purposes. Bajra is a Kharif crop which is sown between May and September and harvested between October and February/March. It is sown either as a pure on mixed crop with cotton, jowar and ragi.

Bajra is a crop of dry and warm climate and is grown in areas of 40-50 cm of annual rainfall. It seldom grows in those areas where the annual rainfall exceeds 100 cm. The ideal temperature for its growth is 25^0-30^0C. Bright sunshine after light showers is very useful in early stages of its growth. Bajra can be grown on poor light sandy soils, black and red soils and on upland gravely soils. It is a rainfed crop and is seldom irrigated.

Table-3.10

Production of Bajra and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Bajra Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	6.76	833.7	-7.6
2001-02	8.28	826.0	-8.3
2002-03	4.72	737.1	-19.2
2003-04	12.11	947.3	4.9
2004-05	7.93	779.6	-12.7
2005-06	7.68	879.3	1.0
2006-07	8.42	886.6	-0.6
2007-08	9.97	936.9	5.0
2008-09	8.89	873.2	-2.1
2009-10	6.51	689.8	-22.7
2010-11	10.37	912.8	2.2
2011-12	10.05	899.9	1.4
2012-13	6.60	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.10

Actual Rainfall and Production of Bajra from 2000-01 to 2012-13

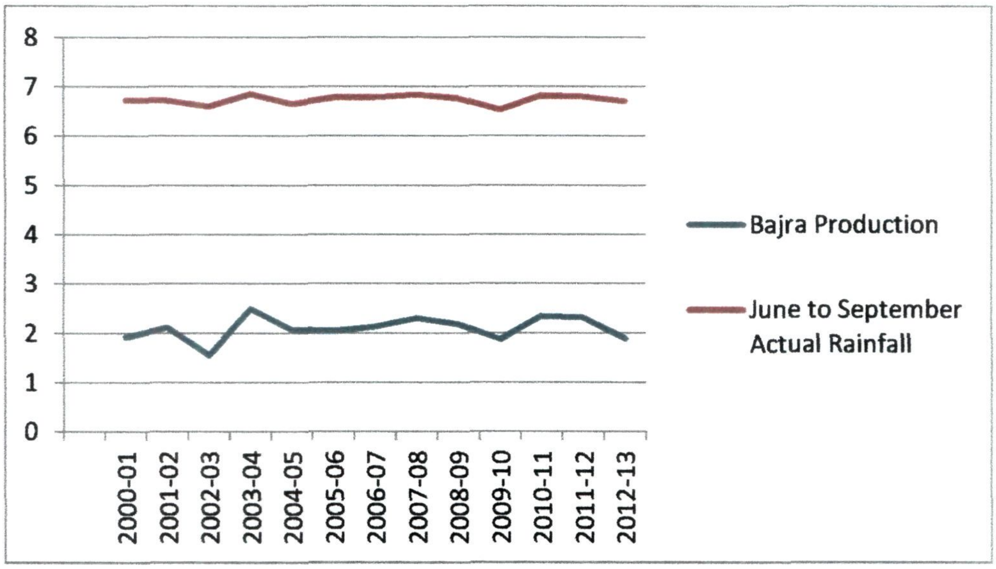


Table-3.10 shows the production of Bajra (in million tonnes) with respect to the all India actual rainfall distribution (in millimeters) for the months from June to September. This period is the growing and harvesting period of Kharif Crops.

It is given in the table that the production of Bajra in 2000-01 was 6.76 million tonnes and the actual rainfall of monsoon season was 833.7 mm during the same year. When rainfall declines to 826 mm the production increased to 8.72 million tonnes in 2001-02. But in 2002-03 when rainfall decreases to 737.1 mm, production also decreases to 4.72 million tonnes. Again in 2003-04 when rainfall increases to 947.3 mm production has increased to 12.11 million tonnes. Similarly in 2004-05, production decreases with the decrease in rainfall. But in 2005-06, rainfall increases but production decreases. Again in 2006-07, when rainfall increases from 879.3 mm to 886.6 mm, production of Bajra also increases from 7.68 million tonnes to 8.42 million tonnes. This will continue till 2012-13. Only in 2001-02 and 2005-06, we see the inverse relationship of production of Bajra and actual rainfall. Otherwise in the remaining years, the production increases with an increase in actual rainfall and vice-versa. In 2011-12 the actual rainfall was 899.9 mm and the production was 10.05 million tonnes, which decreases to 819.5 mm and 6.60 million tonnes respectively in 2012-13.

Figure-3.10 is the line graph which shows the production of Bajra and all India actual rainfall distribution for the months of June to September. It is clear from the graph that except in 2001-02 and 2005-06 all the remaining years shows direct relationship between rainfall and production of Bajra i.e. when rainfall increases production increases and when rainfall decreases production also decreases.

3.3.4 Maize

Maize is mainly a rainfed Kharif crop which is sown just before the onset of monsoon and is harvested after retreat of the monsoon. It requires 50-100 cm of rainfall and it cannot be grown in areas of more than 100 cm rainfall. In the areas of lesser rainfall, the crop is irrigated. For example, more than half of the maize area in Punjab and Karnataka is irrigated. Long dry spell during the rainy season is harmful for maize. Sunshine after showers is very useful for maize. Cool and dry weather helps in ripening of the grain.

Maize usually grows well under temperature varying from 12^0C to 27^0C, although it can tolerate temperatures as high as 35^0C. Frost is injurious to maize and this crop is grown only in those areas where there are about four and a half frost free months in a year.

Table-3.11

Production of Maize and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Maize Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	10.22	833.7	-7.6
2001-02	11.25	826.0	-8.3
2002-03	9.27	737.1	-19.2
2003-04	12.73	947.3	4.9
2004-05	11.48	779.6	-12.7
2005-06	12.16	879.3	-1.0
2006-07	11.56	886.6	-0.6
2007-08	15.11	936.9	5.0
2008-09	14.12	873.2	-2.1
2009-10	12.29	689.8	-22.7
2010-11	16.64	912.8	2.2
2011-12	16.22	899.9	1.4
2012-13	14.89	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.11

Actual Rainfall and Production of Maize from 2000-01 to 2012-13

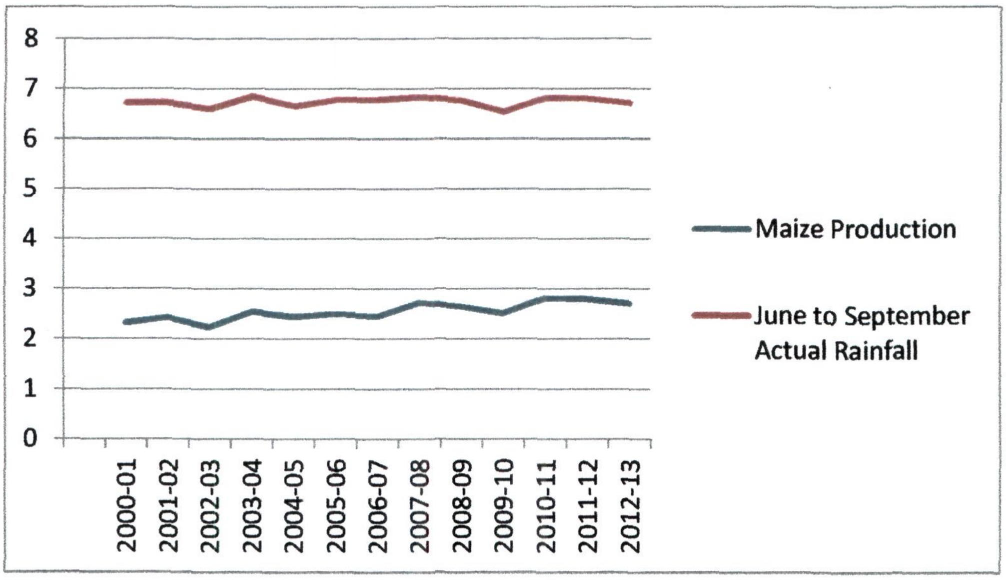


Table-3.11 shows the effect of all India actual rainfall distribution (in millimeters) on the production of Maize (in million tonnes) during the growing and harvesting seasons of Kharif Crops.

In 2000-01, the production of Maize was 10.22 million tonnes and the actual rainfall from June to September was 833.7 millimeters. When rainfall declines to 826 mm in 2001-02 the maize production increases to 11.25 million tonnes, which shows the inverse relationship between production and rainfall. In 2002-03, when rainfall declines to 737.1 mm, production also declines to 9.27 million tonnes. In 2003-04, rainfall increases to 947.3 mm and so the production increases to 12.73 million tonnes. This direct relationship continues till 2005-06. In 2006-07, when rainfall increases from 879.3 mm to 886.6 mm, production decreases from 12.16 million tonnes to 11.56 million tonnes. Once again the production was indirectly affected by the actual rainfall. After this year, from 2007-08 to 2012-13, the production of Maize was directly affected by the actual rainfall. In 2007-08, rainfall increases from 886.6 mm to 936.9 mm and the production of Maize increases from 11.56 million tonnes to 15.11 million tonnes. Thus, the production increases when rainfall increases and vice-versa. In 2012-13, the production was 14.89 million tonnes with respect to the rainfall which was 819.5 mm.

The effect of all India rainfall distribution during monsoon season on the production of maize in Kharif season can also be explained with the help of line graph shown in figure-3.11. The two different lines on the graph shows the production of Maize and the actual rainfall during June to September. It is clear that the production was sometimes directly and sometimes inversely related to the rainfall.

3.3.5 Ragi

Ragi is not a season bound crop and hence can be cultivated throughout the year, if moisture is available in India. It is sown during Kharif season. Sowing takes place between May and August, and harvesting between September and January in areas with annual rainfall of 70-120 cm. It does not tolerate heavy rainfall and requires a dry spell at the time of grain ripening. It grows well in altitudes of 1000-2000m with average temperature of 27^0C. Ragi is cultivated mostly in red lateritic soils. Relatively fertile and well drained soils are the most suitable.

Table-3.12

Production of Ragi and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Ragi Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Parentage Departure
2000-01	2.73	833.7	-7.6
2001-02	2.37	826.0	-8.3
2002-03	1.32	737.1	-19.2
2003-04	1.97	947.3	4.9
2004-05	2.43	779.6	-12.7
2005-06	2.35	879.3	-1.0
2006-07	1.44	886.6	-0.6
2007-08	2.15	936.9	5.0
2008-09	2.04	873.2	-2.1
2009-10	1.89	689.8	-22.7
2010-11	2.19	912.8	2.2
2011-12	2.01	899.9	1.4
2012-13	1.65	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.12

Actual Rainfall and Production of Ragi from 2000-01 to 2012-13

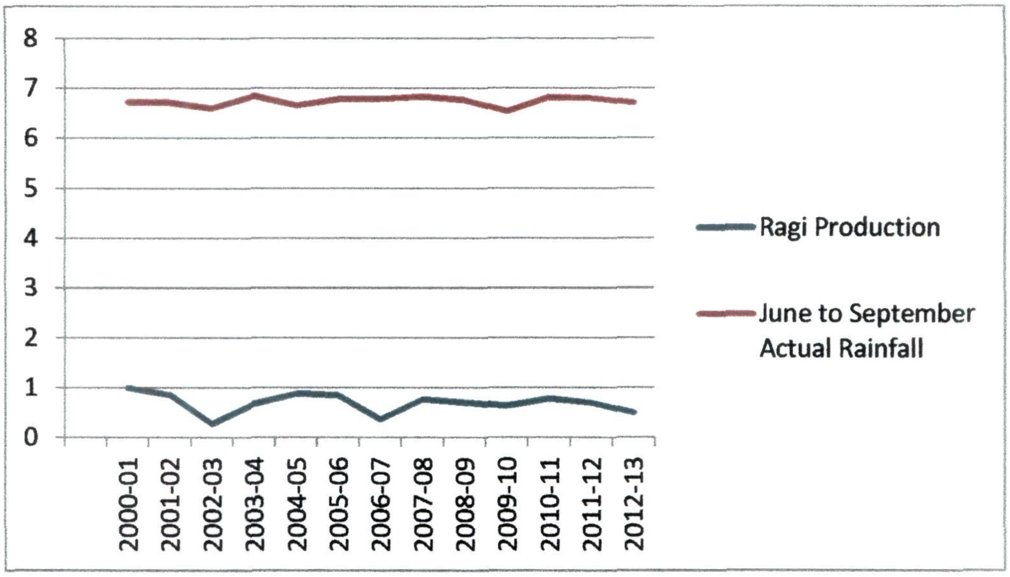


Table-3.12 shows how the production of Ragi (in million tonnes) is affected by the actual rainfall (in millimeters) of the monsoon season during thirteen different years i.e. from 2000-01 to 2012-13.

As shown in the table, the production of Ragi in 2000-01 was 2.73 million tonnes and the rainfall distribution was 833.7 mm. When rainfall declines to 826.0 mm, the production declines to 2.37 million tonnes in 2001-02. Again when rainfall declines to 737.1 mm, production declines to 1.32 million tonnes in 2002-03. In 2003-04, when rainfall increases, production also increases. But in 2004-05, when rainfall decreases from 947.3 mm to 779.6 mm, production of Ragi increases from 1.97 million tonnes to 2.43 million tonnes and vice-versa in 2005-06 and 2006-07. After the inverse relationship from 2007-08, direct relationship was seen between actual rainfall of monsoon season and production of Kharif crop Ragi. When rainfall increases from 886.6 mm in 2006-07 to 936.9 mm in 2007-08, production of Ragi also increases from 1.44 million tonnes in 2006-07 to 2.15 million tonnes in 2007-08. In 2011-12 rainfall was 899.9 mm and production was 2.01 million tonnes, when rainfall declines to 819.5 mm in 2012-13, production of Ragi also declines to 1.65 million tonnes.

Figure-3.12 is the line graph of production of Ragi which is a Kharif crop and the actual rainfall during monsoon season (June to September) during thirteen different years taken on X-axis. It is clear from the figure that in 2004-05, 2005-06 and 2006-07 inverse relationship was seen between production and rainfall, that is, when rainfall increases production decreases and vice versa. Otherwise direct relationship continues till end.

3.3.6 Small Millets

Millets are considered to have been cultivated in India from pre-historic times. Their importance as an article of human food can be realized from the fact that about 30 million acres in India fall under millets.

Millets are generally grown as mixed crops in regions of low rainfall. Most of the millets grown in our country are of short duration, taking, three to four months from sowing to harvesting. In India the crop is grown mainly in Kharif. Sowing takes place between May and September, and harvesting between September and February. It is suited to regions of low rainfall, and can be grown even in tracts which receive only 51 to 60 cm of rainfall.

Table-3.13

Production of Small Millets and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Small Millets Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	0.59	833.7	-7.6
2001-02	0.58	826.0	-8.3
2002-03	0.46	737.1	-19.2
2003-04	0.56	947.3	4.9
2004-05	0.48	779.6	-12.7
2005-06	0.47	879.3	-1.0
2006-07	0.48	886.6	-0.6
2007-08	0.55	936.9	5.0
2008-09	0.44	873.2	-2.1
2009-10	0.38	689.8	-22.7
2010-11	0.73	912.8	2.2
2011-12	0.74	899.9	1.4
2012-13	0.57	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.13

Actual Rainfall and Production of Small Millets from 2000-01 to 2012-13

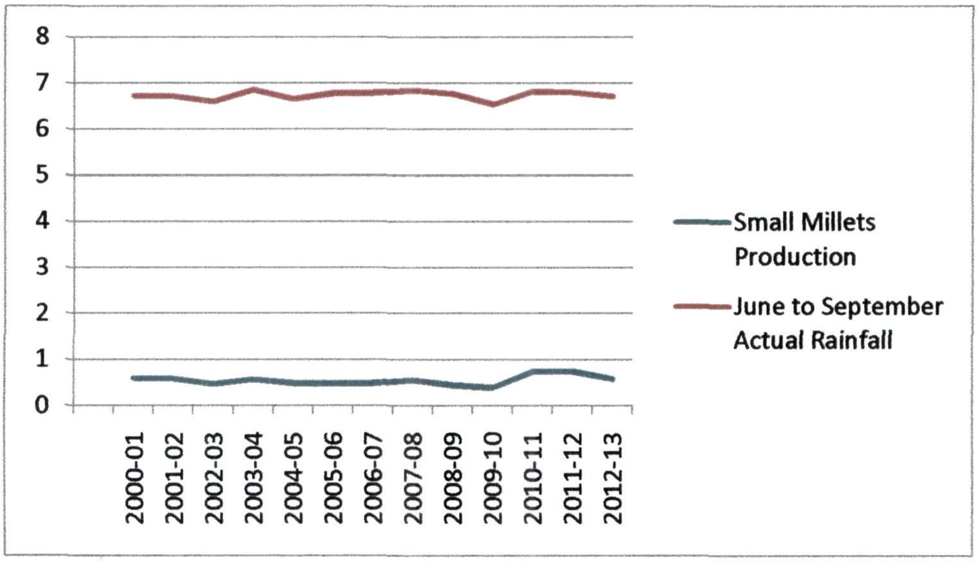


Table-3.13 shows the production of Small Millets (in million tonnes) from 2000-01 to 2012-13 and the effect of monsoon rainfall (in millimeters) on its production during the Kharif season of the above years.

It is given in the table that the actual rainfall during June to September was 833.7 mm in 2000-01 and the percentage departure was -7.6. With respect to this rainfall the production of Kharif crop Small Millets was 0.59 million tonnes in 2000-01. When rainfall declines to 826 mm, the production also declines by 0.01 million tonnes i.e. to 0.58 million tonnes in 2001-02. Again when rainfall declines to 737.1 mm, production also declines to 0.46 million tonnes in 2002-03. The same pattern continues in 2003-04 and 2004-05. But in 2005-06 when rainfall increases, production decreases by 0.01 million tonnes. Again from 2006-07 to 2010-11, the direct relationship continues between rainfall and production of Small Millets i.e. when rainfall increases production increases and vice-versa. In 2011-12 rainfall declines from 912.8 mm to 899.9 mm but production of Small Millets increases from 0.73 million tonnes to 0.74 million tonnes. In 2012-13, when rainfall declines to 819.5 mm production declined to 0.57 million tonnes.

This can also be explained with the help of line graph. Figure-3.13 shows the line graph of production of Small Millets and rainfall of monsoon season (June to

September) through two different lines. The ups and downs shown in the graph clearly explain the relationship between the production and rainfall during thirteen different years taken on X-axis.

3.3.7 Coarse Cereals

Coarse Cereals have been known for their rich nutrient contents and drought resistance quality. These are comparable and at times even better than wheat and rice in their calorie and other nutrients contents. As these crops tolerate longer moisture stress, they are preferred as well as dominate the cropping pattern of drought-prone areas in Central India. Ecologically these are well suited to the drought-prone regions of Deccan Plateau. The cost of production has also been quite low and thus they become affordable for consumption as well as production for the rural poor.

Table-3.14

Production of Coarse Cereals and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Coarse Cereals Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	24.86	833.7	-7.6
2001-02	26.71	826.0	-8.3
2002-03	19.99	737.1	-19.2
2003-04	32.21	947.3	4.9
2004-05	26.36	779.6	-12.7
2005-06	26.73	879.3	-1.0
2006-07	25.61	886.6	-0.6
2007-08	31.89	936.9	5.0
2008-09	28.54	873.2	-2.1
2009-10	23.83	689.8	-22.7
2010-11	33.37	912.8	2.2
2011-12	32.26	899.9	1.4
2012-13	26.33	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.14

Actual Rainfall and Production of Coarse Cereals from 2000-01 to 2012-13

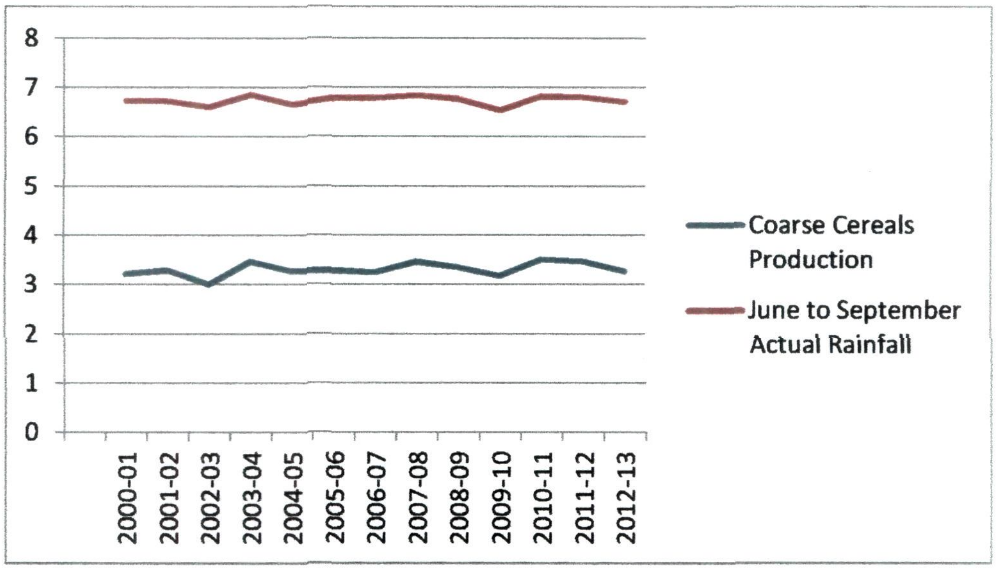


Table-3.14 shows the production of Coarse Cereals (in million tonnes) in Kharif season and all India rainfall distribution, actual and percentage departure, (in millimeters). Here, we see the effect of monsoon rainfall on the production of Coarse Cereals.

As it is clear from the table, in 2000-01, the production of Coarse Cereals was 24.86 million tonnes and actual and percentage departure of rainfall was 833.7 mm and -7.6 respectively. In 2001-02, when rainfall declines to 826 mm, production increases to 26.71 million tonnes. But again in 2002-03, when rainfall declined to 737.1 mm production also declines to 19.99 million tonnes. In 2003-04, rainfall increases to 947.3 mm and so does the production increase to 32.21 million tonnes. In the Kharif season of the year 2001-02 and 2006-07, only, there was inverse relationship between actual rainfall of the Kharif season and the production of Coarse Cereals. Otherwise, all the remaining years, till 2012-13, shows the direct relationship, i.e. when rainfall increases, production of Coarse Cereals also increases and vice versa.

In 2011-12, the production of Coarse Cereals was 32.26 million tonnes and the actual rainfall was 899.9 mm. When rainfall declines to 819.5 mm in 2012-13, production also declines to 26.33 million tonnes.

The effect of monsoon rainfall on the production of Coarse Cereals during Kharif season is shown through line graph in figure-3.14. The two different lines shows the production of Coarse Cereals and the monsoon rainfall i.e. rainfall during June to September. All the years on X-axis shows direct relationship between the two lines except in 2001-02 and 2006-07.

3.3.8 Cereals

The cultivation of cereals varies widely in different countries and depends partly upon the degree of economic development. The conditions and purity of the seed has received increasing attention. Other factors include the nature of the soil, the amount of rainfall, and the techniques applied to promote growth. Cereals are members of the grass family cultivated primarily for their starchy seeds. Wheat, rice, maize, barley, rye, oats, sorghum and millets are common cereals. The growing condition of these cereals is already discussed in previous sections of this chapter.

Table-3.15

Production of Cereals and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Cereals Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	97.64	833.7	-7.6
2001-02	107.23	826.0	-8.3
2002-03	83.07	737.1	-19.2
2003-04	110.83	947.3	4.9
2004-05	98.59	779.6	-12.7
2005-06	105.00	879.3	-1.0
2006-07	105.78	886.6	-0.6
2007-08	114.55	936.9	5.0
2008-09	113.45	873.2	-2.1
2009-10	99.75	689.8	-22.7
2010-11	114.06	912.8	2.2
2011-12	123.79	899.9	1.4
2012-13	111.92	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.15

Actual Rainfall and Production of Cereals from 2000-01 to 2012-13

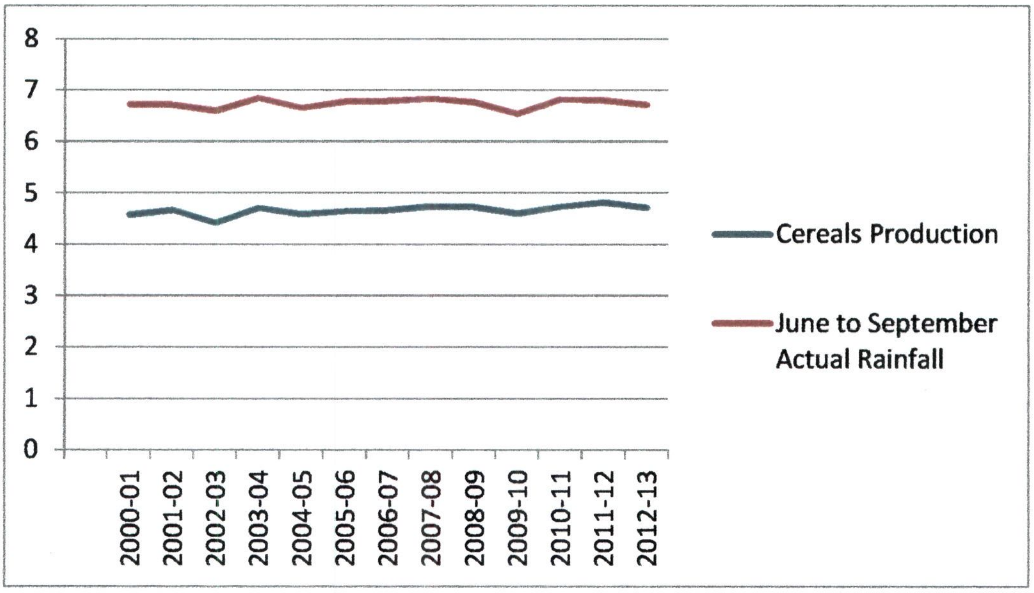


Table-3.15 shows the production of Cereals in Kharif season with respect to the all India actual rainfall distribution for the months of June, July, August and September i.e. the monsoon season which is the growing and harvesting season of Kharif crops. Production is given in million tonnes and rainfall in millimeters.

It is shown in the table that in 2000-01, the production of Cereals was 97.64 *million tonnes* with respect to the actual rainfall of the monsoon season which was 833.7 mm. When rainfall declines to 826 mm, production increases to 107.23 million tonnes in 2001-02. In 2002-03 production decreases with a decrease in the actual rainfall. Again in 2003-04, production of Cereals increases to 110.83 million tonnes with an increase in rainfall to 947.3 mm. This relationship continues till 2010-11, i.e. when rainfall increases, production also increases and vice-versa. In 2011-12 when rainfall declines from 912.8 mm to 899.9 mm, production of Cereals increases from 114.06 million tonnes to 123.79 million tonnes. But again in 2012-13, when rainfall declines to 819.5 mm, production also declines to 111.92 million tonnes.

Figure-3.15 shows the line graph for the production of Cereals during Kharif season and actual rainfall during June to September which are growing and harvesting months of Kharif crops. Sometimes the production of Cereals increases with an increase in rainfall and vice-versa. Sometimes it decreases with an increase in rainfall and vice-versa.

3.3.9 Total Pulses

Pulses include a number of crops which are mostly leguminous and provide much needed vegetable proteins to a largely vegetarian population of India. Though gram and tur (pigeon pea) are the more important pulses, several other pulses such as urd (black gram), mung (green gram), masur (lentil), matar (peas) etc. are also grown.

Tur (Pigeon pea) is the second most important pulse of India next to gram. It is chiefly grown as a Kharif crop but in areas of mild winters it is grown as a rabi crop also. It is grown as a dry crop mixed with other Kharif crops like jowar, bajra, ragi, maize, cotton, groundnut, etc. and in seldom grown as a single crop. Its conditions of growth are more or less similar to those of other pulses and millets.

Table-3.16

Production of Total Pulses and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Total Pulses Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	4.45	833.7	-7.6
2001-02	4.84	826.0	-8.3
2002-03	4.15	737.1	-19.2
2003-04	6.17	947.3	4.9
2004-05	4.72	779.6	-12.7
2005-06	4.87	879.3	1.0
2006-07	4.80	886.6	-0.6
2007-08	6.40	936.9	5.0
2008-09	4.69	873.2	-2.1
2009-10	4.20	689.8	22.7
2010-11	7.12	912.8	2.2
2011-12	6.16	899.9	1.4
2012-13	5.26	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.16

Actual Rainfall and Production of Total Pulses from 2000-01 to 2012-13

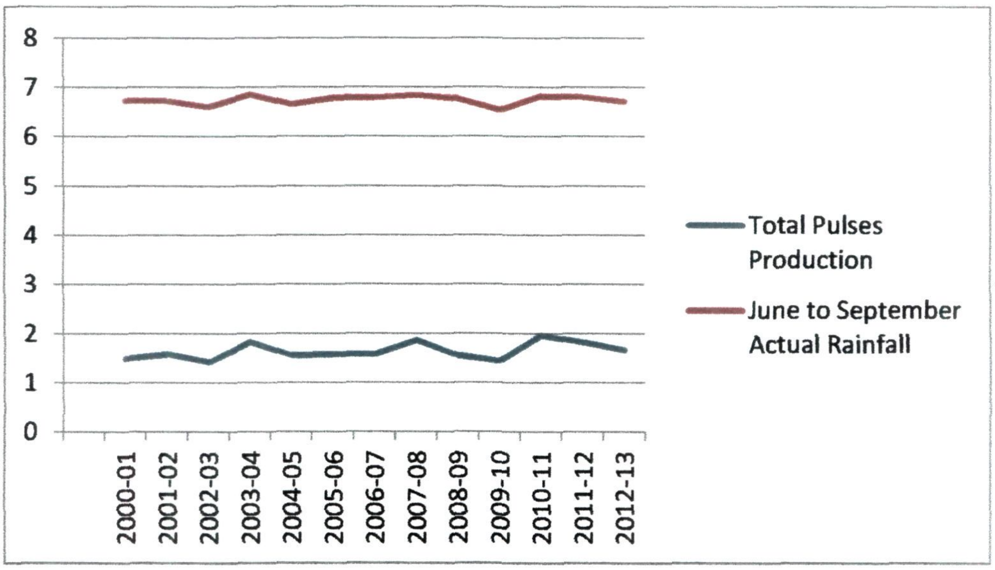


Table-3.16 shows the effect of monsoon rainfall on the production of Total Pulses in Kharif season from 2000-01 to 2012-13. The production was given in million tonnes and the rainfall was given in millimeters.

The table shows that the production of Total Pulses in 2000-01 was 4.45 million tonnes and the rainfall for Kharif season was 833.7 mm. When rainfall declines to 826 mm in 2001-02, production increases to 4.84 million tonnes. In 2002-03, production was 4.15 million tonnes with decrease in rainfall to 737.1 mm. Again in 2003-04, 2004-05 and 2005-06, when rainfall increases, production also increases and when rainfall decreases, production also decreases. But in 2006-07, when rainfall increases to 886.6 mm, production of Total Pulses declines to 4.8 million tonnes. From 2007-08 till 2012-13, the production of Total Pulses and monsoon rainfall was directly related. In 2011-12, rainfall was 899.9 mm and the production of Total Pulses was 6.16 million tonnes. When rainfall declines to 819.5 mm in 2012-13, production of Total Pulses also declines to 5.26 million tonnes.

Figure-3.16 shows the effect of monsoon rainfall on the production of Total Pulses in Kharif season from 2000-01 to 2012-13 through the line graph. The two line on the graph shows the production of Total Pulses and monsoon rainfall during June to September with respect to the years taken on X-axis.

3.3.10 Total Foodgrains

Total foodgrains of Kharif season include, Rice, Jowar, Bajra, Maize, Ragi, Small Millets, Cereals, Coarse Cereals, Tur, Urad, Moong etc. The climatic condition for cultivation of these crops is discussed previously in this chapter.

Table-3.17

Production of Total Foodgrains and All India Rainfall Distribution from 2000-01 to 2012-13

Year	Total Foodgrains Production (in million tonnes)	Rainfall (June – September) (in millimetres)	
		Actual	Percentage Departure
2000-01	102.09	833.7	-7.6
2001-02	112.07	826.0	-8.3
2002-03	87.22	737.1	-19.2
2003-04	117.00	947.3	4.9
2004-05	103.31	779.6	-12.7
2005-06	109.87	879.3	-1.0
2006-07	110.57	886.6	-0.6
2007-08	120.95	936.9	5.0
2008-09	118.14	873.2	-2.1
2009-10	103.95	689.8	-22.7
2010-11	121.18	912.8	2.2
2011-12	129.94	899.9	1.4
2012-13	117.18	819.5	-7.6

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2012-13) at www.agricoop.co.in

Figure- 3.17

Actual Rainfall and Production of Total Foodgrains from 2000-01 to 2012-13

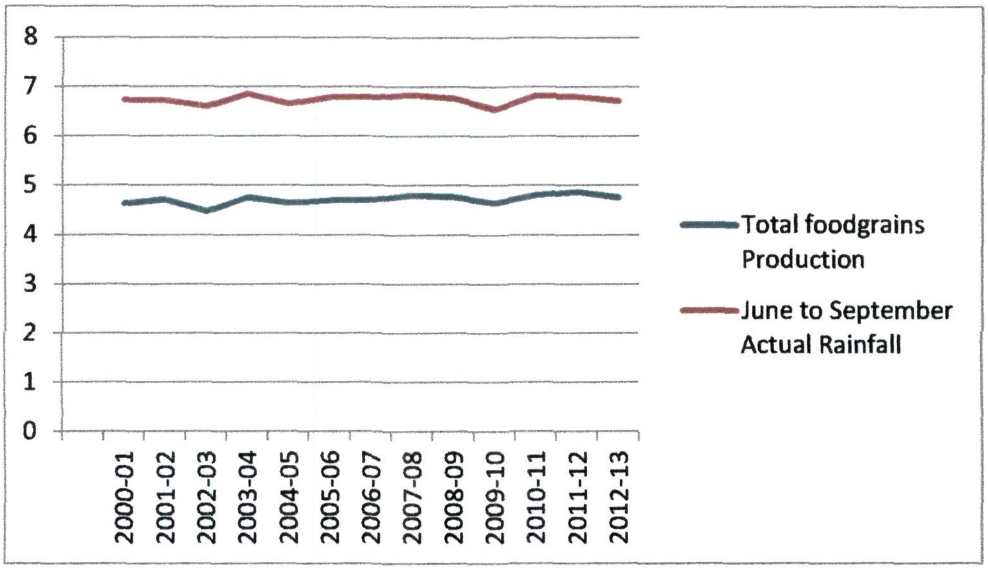


Table-3.17 shows the Total Foodgrains production in million tonnes and the effect of all India monsoon rainfall distribution (in millimeters) during the Kharif season of 13 different years from 2000-01 to 2012-13.

The production of Total Foodgrains in 2000-01 was 102.09 million tonnes and rainfall was 833.7 mm. In 2001-02, when rainfall declines to 826 mm, production of Total Foodgrains increases to 112.07 million tonnes. After this year, in 2011-12, this relationship was again seen, i.e., when rainfall declines from 912.8 mm to 899.9 mm, production increases from 121.18 million tonnes to 129.94 million tonnes. While in all the remaining years, the production of total foodgrains was directly affected by monsoon rainfall i.e. when rainfall increases, production increases and vice-versa.

This direct and inverse relationship can be seen on the line graph of figure-3.17, which shows the production of total foodgrains and actual rainfall during June to September through two different lines during years from 2000-01 to 2012-13 taken on X-axis.

3.4 Climate Change, Livestock and Fisheries

Livestock is an integral part of India's agricultural economy and plays an important role in providing livelihood support to the rural population. Livestock sector contributes to national economy in general and to agricultural economy in particular. Apart from this it provides employment generation opportunities, asset creation, coping mechanism against crop failure and social and financial security. Livestock is the main source of animal protein for the population. The small and marginal farmers and landless labourers own majority of the livestock resources.

Fish is an important source of protein and it provide livelihood for millions of people as well as providing valuable foreign exchange earnings to the country. It requires proper handling, processing and distribution, if it is to be utilized in a cost effective and efficient way. Fisheries are next to agriculture in terms of providing employment and food supply. Fish is an important source of quality protein and cheaper in cost compared to other source of animal protein. About 35 percent of Indian population is fish eater. Fisheries provide employment and sustenance to sizeable sections of the society in rural India, especially weaker sections.

3.4.1 Effects of Climate Change on Livestock

The possible effects of climate change on food production are not limited to crops and agricultural production. Climate Change will have far-reaching consequences for dairy, meat and wool production, mainly arising from its impact on grassland and rangeland productivity. Head distress suffered by animals will reduce the rate of animal feed intake and result in poor growth performance (Rowlinson, 2008).

Livestock is a key asset for poor people, fulfilling multiple economic, social and risk management functions. Livestock sector contributes to climate change as well as affected by it. The impact of climate change is expected to heighten the vulnerability of livestock systems and reinforce exiting factors that are affecting livestock production systems, such as rapid population and economic growth, rising demand for food (including livestock) and products (Gills and Smith, 2008). For rural communities, losing livestock assess could result in chronic poverty and have a lasting effect on livelihoods.

Climate change affects livestock both directly and indirectly. The direct effects of climate change will include; higher temperature and changing rainfall patterns, which could translate into the increased spread of existing vector-borne disease and macroparasites, accompanied by the emergence and circulation of new diseases. In some areas, climate change could also generate new transmission models. Houghton et. al. (2001) concluded that direct effects from air, temperature, humidity, wind speed and other climate factors influence animal performance; growth, milk production, wool production and reproduction. These effects will be evidence in both developed and developing countries, but the pressure will be greatest on developing countries because of their lack of resources, knowledge, veterinary and extension services, and research technology department. The effects of rising temperatures vary, depending on when and where they occur. A rise in temperature during the winter months can reduce the cold stress experienced by livestock remaining outside. Warmer weather reduces the amount of energy required to feed the animals and keep them in heated facilities (FAO, 2007 b).

Some of the indirect effects will be; changes in feed resources linked to the carrying capacity of rangelands, the buffering abilities of ecosystems, intensified desertification processes, increased scarcity of water resources and decreased grain production. Other indirect effects will be linked to the expected shortage of feed arising from the increasingly competitive demands of foods, feed and fuel production, and land use systems (Thornton et al., 2008).

The following tables provides the all India estimates of production of Milk, Egg, Meat and Wool from 2000-01 to 2011-12.

Table- 3.18

All India Estimates of Production and Per Capita Availability of Milk from 2000-01 to 2011-12

Year (March to February)	Milk Production (Million Tonnes)	Human Population (Million Nos.)	Per Capita Availability (Gram/day)
2000-01	80.6	1019	217
2001-02	84.4	1040	222
2002-03	86.2	1056	224
2003-04	88.1	1072	225
2004-05	92.5	1089	233
2005-06	97.1	1106	241
2006-07	102.6	1122	251
2007-08	107.9	1138	260
2008-09	112.2	1154	266
2009-10	116.4	1170	273
2010-11	121.8	1186	281
2011-12	127.9	1210	290

Source: Basic Animal Husbandry and Fisheries Statistics (2013), Animal Husbandry Department at www.indiastat.com

The above table 3.18 gives the All India estimates of production and per capita availability of milk from 2000-01 to 2011-12. It is clear from the table that the production of milk has continuously increasing from 80.6 million tonnes in 2000-01 to 127.9 million tonnes in 2011-12. On the other hand, the human population has also increased from 1019 million in 2000-01 to 1210 million in 2011-12. Thus the per capita availability of milk was 217 gram per day in 2000-01 and 290 gram per day in 2011-12.

Table- 3.19

All India Estimates of Production and Per Capita Availability of Egg from 2000-01 to 2011-12

Year (March to February)	Eggs Productio (Million Nos.)	Human Population (Million Nos.)	Per Capita Availability (Nos./Annum)
2000-01	36632	1019	36
2001-02	38729	1040	37
2002-03	39823	1056	38
2003-04	40403	1072	38
2004-05	45201	1089	42
2005-06	46235	1106	42
2006-07	50663	1122	45
2007-08	53565	1138	47
2008-09	55562	1154	48
2009-10	60267	1170	51
2010-11	63024	1186	53
2011-12	66450	1210	55

Source: Basic Animal Husbandry and Fisheries Statistics (2013), Animal Husbandry Department at www.indiastat.com

The above table 3.19 shows the all India estimates of production and per capita availability of egg from 2000-01 to 2011-12. According to the table the egg production in 2000-01 was 36632 million which is approximately doubled to 66450 million in 2011-12. And so does the per capita availability have increased from 36 eggs per annum person for 1019 million population in 2000-01 to 55 eggs per annum per person for 1210 million population in 2011-12.

Table- 3.20

All India Estimates of Production of Wool from 2000-01 to 2011-12

Year (March to February)	Wool Production (Million Kilogram)
2000-01	48.4
2001-02	49.5
2002-03	50.5
2003-04	48.5
2004-05	44.6
2005-06	44.9
2006-07	45.1
2007-08	43.9
2008-09	42.8
2009-10	43.1
2010-11	43.0
2011-12	44.7

Source: Basic Animal Husbandry and Fisheries Statistics (2013), Animal Husbandry Department at www.indiastat.com

Table 3.20 provides the all India estimates of production of wool from 2000-01 to 2011-12 in million Kilograms. The production of wool was 48.4 million kilograms in 2000-01 which increased to 49.5 million kilograms in 2001-02 and then to 50.5 million kilograms in 2002-03. After that it decreases to 48.5 million kilograms in 2003-04 then to 44.6 million kilograms in 2004-05. In 2005-06 it slightly increased to 44.9 million kilograms and then to 45.1 million kilograms in 2006-07. In 2007-08 it again declines to 43.9 million kilograms and to 42.8 million kilograms in 2008-09. In 2009-10, the production of wool was 43.1 million kilograms which slightly decreased to 43.0 million kilograms in 2010-11 and then increased to 44.7 million kilograms in 2011-12.

Table- 3.21

All India Estimates of Production of Meat from 2000-01 to 2011-12

Year (March to February)	Meat Production (Million Tonnes)
2000-01	1.9
2001-02	1.9
2002-03	2.1
2003-04	2.1
2004-05	2.2
2005-06	2.3
2006-07	2.3
2007-08	4.0
2008-09	4.2
2009-10	4.5
2010-11	4.9
2011-12	5.5

Source: Basic Animal Husbandry and Fisheries Statistics (2013), Animal Husbandry Department at www.indiastat.com

Table 3.21 gives the all India estimates of production of meat from 2000-01to 2011-12 in million tonnes. The production of meat in 2000-01 and 2001-02 was 1.9 million tonnes same in both the year which increases to 2.1 million tonnes in 2002-03 and remains constant in 2003-04. Again it increases to 2.2 million tonnes in 2004-05 and to 2.3 million tonnes in 2005-06 and remain same in 2006-07. In 2007-08, the production of meat was 4.0 million tonnes which goes on increasing and was maximum in 2011-12 i.e. 5.5 million tonnes.

Table- 3.22

Value of Output and Gross Domestic Product from Livestock Sector

from 2004-05 to 2011-12

Year	At Current Prices (Rs. Crore)		At Constant Prices – 2004-05 (Rs. Crore)	
	Value of Output	Gross Domestic Production	Value of Output	Gross Domestic Production
2004-05	180034	119333	180034	119333
2005-06	193450	127518	187779	126765
2006-07	215350	142695	195850	133338
2007-08	247180	169296	204454	141398
2008-09	292146	200440	217641	153219
2009-10	346147	237059	226676	161382
2010-11	401160	276105	239014	170293
2011-12	459051	327838	250775	178601

Source: National Accounts Statistics (2013), Central Statistical Organization at www.indiastat.com

The above table-3.22 gives the value of output and gross domestic product from livestock sector at current and constant prices from 2004-05 to 2011-12. In 2004-05 the value of output at current prices was rupees 180034 crores and the gross domestic product was rupees 119333 crores. This increased to rupees 459051 crores for the value of output and rupees 327838 for gross domestic production. The constant prices were taken for the year 2004-05. The value of output was rupees 180034 crores and gross domestic production was rupees 119333 crores same as that of current prices. But the value of output and gross domestic product was rupees 250775 crores and rupees 178601 crores respectively in 2011-12.

3.4.2 Effects of Climate Change on Fisheries

Climate change represents a threat to the sustainability of capture fisheries and aquaculture development. The consequences of gradual warming on a global scale and the associated physical changes will become increasingly evident, as will the impact of more frequent extreme weather events. The effects of increased pressure on fisheries (environmental pollution, environmental degradation resulting from unsustainable aquaculture practices, intensive exploitation of marine resources), together with future climate change, will have a bearing on a very large number of fisheries in different socio-economic and geographical contexts.

Kibuka – Musoke (2007) identifies both positive and negative impacts of climate change on fisheries. The projected climate change will generally be positive for aquaculture, which is often limited by cold weather. Since many of the changes will entail warmer nights and winters, there should be longer periods of growth and growth should be enhanced. The cost of making structures ice-resistant and of heating water to optimum temperatures should also be lowered. By developing appropriate technologies, farmers can use flooded and saline areas no longer suitable for crops to cultivate fish. Farmers can also recycle water used for fish culture to moderate swings between drought and flood.

Climate change will have a negative impact on fisheries both directly and indirectly. Fisheries will be impacted by changing water levels and flooding events; temperature changes will cause a shift in the range of fish species (in different geographical areas) and a disruption to the reproductive patterns of fish. Rising sea levels could also affect important fishery nursery areas. Warming can increase disease transmission and have an influence on marine pathogens. Because of their comparatively small or weak economies, a number of countries that are heavily dependent on fish have low capacity to adapt to change (World fish center, 2007).

The following table provides the state wise production of fish during 2011-12 in tonnes.

Table- 3.23

Fish Production during 2011-12 in tonnes

S. No.	State/Uts	Marine	Inland	Total
1	Andhra Pradesh	433278	1169890	1603168
2	Arunachal Pradesh	0	3300	3300
3	Assam	0	228621	228621
4	Bihar	0	344470	344470
5	Chhattisgarh	0	250695	250695
6	Goa	86205	3751	89956
7	Gujarat	692488	91231	783719
8	Haryana	0	106000	106000
9	Himachal Pradesh	0	8045	8045
10	Jammu & Kashmir	0	19850	19850
11	Jharkhand	0	91676	91676
12	Karnataka	347383	199053	546436
13	Kerala	553177	140031	693208
14	Madhya Pradesh	0	75405	75405
15	Maharashtra	433684	145110	578794
16	Manipur	0	22219	22219
17	Meghalaya	0	4768	4768
18	Mizoram	0	2928	2928
19	Nagaland	0	6840	6840
20	Orissa	114295	267533	381828
21	Punjab	0	97620	97620

22	Rajasthan	0	47850	47850
23	Sikkim	0	280	280
24	Tamil Nadu	426735	184753	611488
25	Tripura	0	53335	5335
26	Uttarakhand	0	3834	3834
27	Uttar Pradesh	0	429718	429718
28	West Bengal	182020	1290025	1472045
29	Andaman & Nicobar Isd.	35072	192	35264
30	Chandigarh	0	96	96
31	Dadra & Nagar Haveli	0	50	50
32	Daman & Diu	17429	0	17429
33	Delhi	0	740	740
34	Lakhshadweep	12372	0	12372
35	Pondicherry	37608	4795	42403
	Total	**3371746**	**5294704**	**8666450**

Source: Basic Annual Husbandry and Fisheries Statistics (2013), Department of Fisheries at www.indiastat.com

According to the table-3.23 the total production of fish in 2011-12 was maximum in Andhra Pradesh, that is 1603168 tonnes followed by West Bengal with 1472045 tonnes production of fish during the same year. Gujarat, Kerala and Tamil Nadu also has a large production of fish with 783719, 693208 and 611488 tonnes respectively. The production of fish was minimum in Dadra and Nagar Haveli, that is, 50 tonnes only followed by Chandigarh with 96 tonnes only. The total production of fish in all over India during 2011-12 was 8666450 tonnes.

Region specific ecosystem-based approaches are needed to address the impact of climate change on fisheries and fishing communities. While it is important to have an understanding of both the regional and the global impact that climate change will have on fishing communities in developing countries, it is essential that context - specific vulnerability assessments are carried out to inform the development of locally tailored strategies to support fishing communities in adapting to a changed environment.

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Chapter-4

Climate Change and Rural Poor

CLIMATE CHANGE AND RURAL POOR

4.1 Introduction

The United Nations Framework Convention on Climate Change (UNFCCC) defines Climate Change as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods."

Climate is a part of a complex system, which is defined by UNFCCC as the totality of the atmosphere, hydrosphere, biosphere and geosphere and their interactions, which functions as a component of the entire ecosystem. This is perhaps the reason why it is not possible for most of the literature to omit environment in any analysis related to climate change and poverty. Considering the fact that climate change is a part of the environment will perhaps enhance the understanding of the linkages between poverty and climate change.

Climate change will compound existing poverty. The developing nations will be most striked by the adverse impacts of climate change because of their geographical and climatic conditions, their high dependence on natural resources, and their limited capacity to adapt to a changing climate. Within these countries, the most vulnerable are those poorest who have the least resources and the least capacity to adapt.

The impacts of climate change and the vulnerability of poor communities to climate change, vary greatly, but generally, climate change is superimposed on existing vulnerabilities. Further climate change will reduce access to drinking water, negatively affect the health of poor people and pose a threat to food security in many countries in Africa, Asia and Latin America. In some areas, where the choices for livelihood are limited and decreasing crop yield lead to the situation of famines, migration there might be the only solution.

4.2 Climate Change, Agriculture and Rural Livelihoods

Climate change is a major challenge for agriculture, food security and livelihood of billions of people including the rural poor. Agriculture sector is most vulnerable to climate change due to its high dependence on climate and weather. People living in rural areas mostly depend on agriculture for their livelihood and therefore they tend to be poorer as compared with those living in urban areas. Food security and livelihood depends on sustainable agriculture. Agriculture plays a vital role in contributing to all the three components of food security namely, adequate food availability, access and abruption which are required in achieving food security in rural areas.

Agriculture is part of the problem for adverse impact of climate change. Human actions on production, exchange and consumption relating to agriculture and rural development would have impact on climate change. Factors responsible for increase in Green House Gases (GHGs) are intensification due to green revolution, diversification, and increase in rural non-farm activities. There has been intensification of agriculture due to green revolution. The nature of agriculture has been changing over time. There has been diversification in cropping patterns from traditional cereals to vegetables, fruits and flowers which are of high value. There has been a rapid growth in rural non-farm economy including manufacturing in rural towns.

The development in agriculture sector due to intensification, diversification and growth in rural non-farm economy have led to negative consequence on environment. Intensification of agricultural production in irrigated and favourable rainfed environment together with flawed incentives due to inappropriate policies has caused substantial environmental degradation. Cropped area is expanded into forested and woodland areas which increased soil erosion. Water and land quality problems are also added due to intensive livestock production (Rosegrant and Hazell, 2000).

In India, agriculture sector is already facing many problems relating to sustainability, such as small size of the farms, stagnant fields, change in prices, water supply, soil erosion, natural calamities, etc. Population is increasing further and with the increase in income of the people in the country, there will be increase in demand for food which in turn puts additional pressure on sustainable food production. The economy experienced one of the worst food crisis with rise in prices of major food grains and other food products consequently pushing more people towards poverty and extreme hunger. The adverse effects of climate change on future food and agricultural production may further exacerbate high prices, thereby adding further pressure on agriculture adversely affecting the poor.

4.2.1 Impacts of Climate Change on Agriculture

The Impact of climate change on agricultural production and consumption depends on a combination of natural and human actions. The climate change can have both positive and negative effects depending on the location. For example, in some areas climate change reduces crop yields which it increases in some other areas. Similarly human actions will have both positive and negative effects on agricultural production and consumption. These actions can have positive impact on adaptation and mitigation of climate change and reduce the impact of climate change on agriculture, food security and livelihoods. It can have negative impact if unsustainable production and consumption practices are followed.

Climate change and agriculture both are interconnected and climate change over the next century may have major effects on food availability and crop production. It is predicted that by 2050, there would not be any glacier in the world and melting of ice would results in recurrent floods and significant rise in sea level (Cassman, K.G., 2007). Floods will wipe out standing crops; forest fire will be a common occurrence in drought-affected areas, more water will be needed for irrigation, cultivable land will become sterile, and rainfall at regional level show signs of an increasing or decreasing trend. These changes will in turn worsen the existing ecosystem. Also, the crop patterns will be affected by the changes in agro systems. In India, the effects of global warming are likely to be more severe.

A growing world population combined with the steady effects of climate change is forecast to create a global food shortage in the next 10 years. India is not exceptional. its 52 percent working populations depend on agriculture and nearly 70 percent population resided in rural areas where agriculture is largest support to livelihoods (Economic Outlook, 2010-ll). In India, as climate changes, there will be increase in the demand for food to 276 million tonnes by 2021 as against current production of 230 million tonnes that may increase the competition for resources use such as land, water, capital, labour and other precious natural resources.

In India, out of the total 329 million hectares of geographical area, 174 million hectares or 53 percent of the total land area is suffering from serious degradation. Of this, 144 million hectares area is subjected to water and wind erosion and 30 million hectares is degraded through special problems like ravines, salinity, water logging etc. (Koty Reddy T., 2010). One-third of our land under forests, nearly two-thirds of land under agriculture and nearly all cultivable waste lands, permanent pasture and grazing lands are in urgent need of conservation measures (K.G. Tejwani, 1982). Land degradation due to overgrazing has led to desert like conditions in many parts of the country.

The following tables provide all India area (in million hectares), production (in million tonnes) and yield (in Kg per hectare) of some common crops mainly Rice, Wheat, Coarse Cereals and Total Pulses along with coverage under irrigation (in percent) which is the main source of rural livelihoods.

Table-4.1

All India Area, Production and Yield of Rice along-with coverage under Irrigation from 2000-01 to 2010-11

Year	Area Million Hectares	Production Million Tonnes	Yield Kg / Hectare	Area Under Irrigation (Percent)
2000-01	44.71	84.98	1901	53.6
2001-02	44.90	93.34	2079	53.2
2002-03	41.18	71.82	1744	50.2
2003-04	42.59	88.53	2077	52.6
2004-05	41.91	83.13	1984	54.7
2005-06	43.66	91.79	2102	56.0
2006-07	43.81	93.36	2131	56.7
2007-08	43.91	96.69	2202	56.9
2008-09	45.54	99.18	2178	NA
2009-10	41.85	89.13	2130	NA
2010-11	36.95	95.98	2177	NA

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2010-11) at www.agricoop.co.in

Table-4.1

All India Area, Production and Yield of Rice along-with coverage under Irrigation from 2000-01 to 2010-11

Year	Area Million Hectares	Production Million Tonnes	Yield Kg / Hectare	Area Under Irrigation (Percent)
2000-01	44.71	84.98	1901	53.6
2001-02	44.90	93.34	2079	53.2
2002-03	41.18	71.82	1744	50.2
2003-04	42.59	88.53	2077	52.6
2004-05	41.91	83.13	1984	54.7
2005-06	43.66	91.79	2102	56.0
2006-07	43.81	93.36	2131	56.7
2007-08	43.91	96.69	2202	56.9
2008-09	45.54	99.18	2178	NA
2009-10	41.85	89.13	2130	NA
2010-11	36.95	95.98	2177	NA

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2010-11) at www.agricoop.co.in

Figure- 4.1

Area, Production and Yield of Rice from 2000-01 to 2010-11

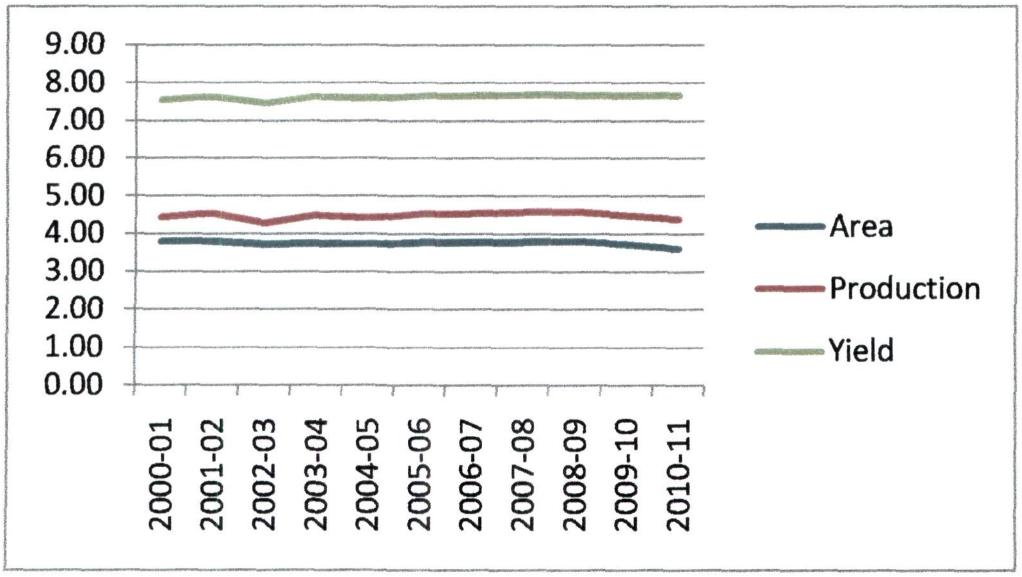


Table-4.1 shows that in 2000-01 the area under cultivation for rice crop was 44.71 million hectares and the production was 84.98 million tonnes and yield was 1901 Kg per hectare. However the area under irrigation was 53.6 percent during the same year. In 2001-02, the area increases a little to 44.90 million hectares but the production and yield increases more to 93.34 million tonnes and 2079 Kg per hectare respectively. But the area under irrigation decreases to 53.2 percent. In 2002-03, area, production and yield all declines to 41.18 million hectares, 71.82 million tonnes and 1744 Kg per hectare respectively. This goes to the maximum of 45.54 million hectares area and 99.18 million tonnes production in 2008-09 and to the minimum of 36.95 million hectares area and 80.41 million tonnes production of rice in 2010-11. However the yield was maximum in 2007-08 i.e. 2202 Kg per hectare and minimum in 2005-06 i.e. 2102 Kg per hectare.

The Area, production and yield of rice from 2000-01 to 2010-11 can be clearly understood will the help of line graph shown in figure 4.1 above.

Table-4.2

All India Area, Production and Yield of Wheat along-with coverage under Irrigation from 2000-01 to 2009-10

Year	Area Million Hectares	Production Million Tonnes	Yield Kg / Hectare	Area Under Irrigation (percent)
2000-01	25.73	69.68	2708	88.1
2001-02	26.34	72.77	2762	87.4
2002-03	25.20	65.76	2610	88.0
2003-04	26.60	72.15	2713	88.4
2004-05	26.38	68.64	2602	89.4
2005-06	26.48	69.35	2619	89.6
2006-07	27.99	75.81	2708	90.2
2007-08	28.04	78.57	2802	90.9
2008-09	27.75	80.68	2907	NA
2009-10	28.52	80.80	2830	NA

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2010-11) at www.agricoop.co.in

Figure- 4.2

Area, Production and Yield of Wheat from 2000-01 to 2009-10

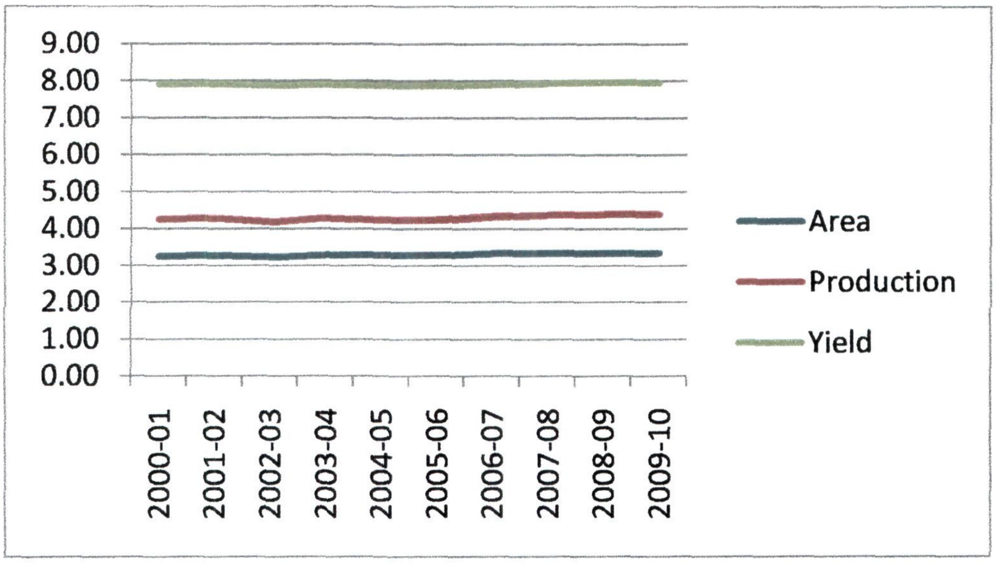


Table-4.2 shows that the production of wheat in 2000-01 was 25.73 million tonnes and yield was 2708 Kg per hectare. While the area under cultivation and irrigation was 25.73 million hectares and 88.1 percent respectively. In 2001-02 the area, production and yield slightly increases to 26.34 million hectares, 72.77 million tonnes and 2762 Kg per hectare respectively while the area under irrigation slightly declines to 87.4 percent. The area and production goes to the maximum of 28.52 million hectares and 80.71 million tonnes in 2009-10. But the yield was maximum in 2008-09 i.e. 2907 Kg per hectares.

Figure 4.2 above shows the line graph of area, production and yield of wheat as given in table 4.2 and explained above.

Table-4.3

All India Area, Production and Yield of Coarse Cereals along-with coverage under Irrigation from 2000-01 to 2010-11

Year	Area Million Hectares	Production Million Tonnes	Yield Kg / Hectare	Area Under Irrigation (percent)
2000-01	30.26	31.08	1027	12.5
2001-02	29.52	33.38	1131	11.3
2002-03	26.99	26.07	966	11.0
2003-04	30.80	37.60	1221	6.6
2004-05	29.03	33.47	1153	6.6
2005-06	29.04	34.07	1172	13.0
2006-07	28.71	33.92	1182	13.4
2007-08	28.48	40.75	1431	14.2
2008-09	27.45	40.04	1459	NA
2009-10	27.64	33.77	1222	NA
2010-11	20.94	43.68	1348	NA

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2010-11) at www.agricoop.co.in

Figure- 4.3

Area, Production and Yield of Coarse Cereals from 2000-01 to 2010-11

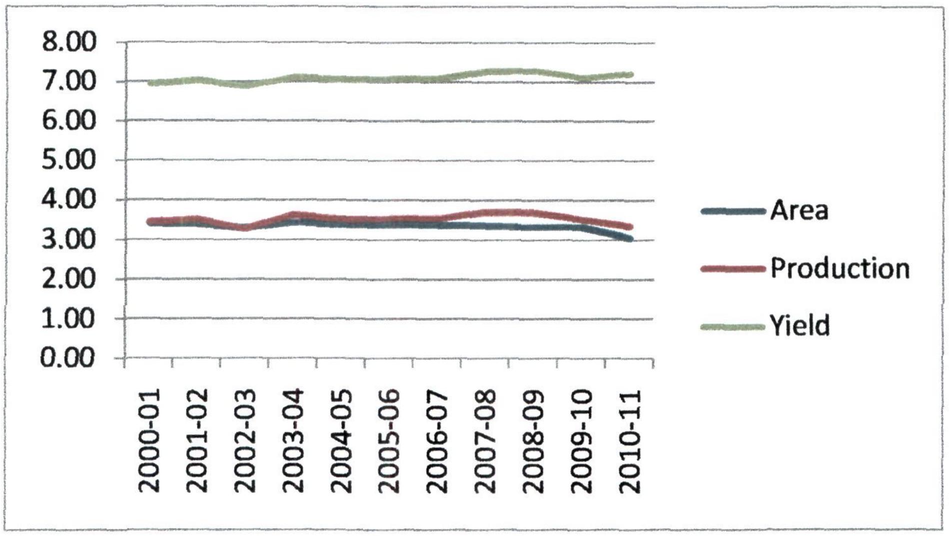


Table-4.3 gives the production and yield of coarse cereals as 31.08 million tonnes and 1027 Kg per hectare respectively in 2000-01. Also the area under cultivation and irrigation was 30.26 million hectares and 12.5 percent respectively during that year. In 2001-02, the area under cultivation declines to 29.52 million hectares but the production and yield increases to 33.38 million tonnes and 1131 Kg per hectare respectively. In 2002-03, area, production and yield all declines to 26.99 million hectares, 26.07 million tonnes and 966 Kg per hectare respectively. The maximum area under cultivation was 30.80 million hectares in 2003-04 and minimum area was 20.94 million hectares in 2010-11. Maximum production of coarse cereals was 40.75 million tonnes in 2007-08 and minimum was 26.07 million tonnes in 2002-03. Maximum yield was 1459 Kg per hectare in 2008-09 and minimum was 966 Kg per hectare in 2002-03.

This maximum and minimum production and yield can be clearly seen through the graph shown above in figure 4.3.

Table-4.4

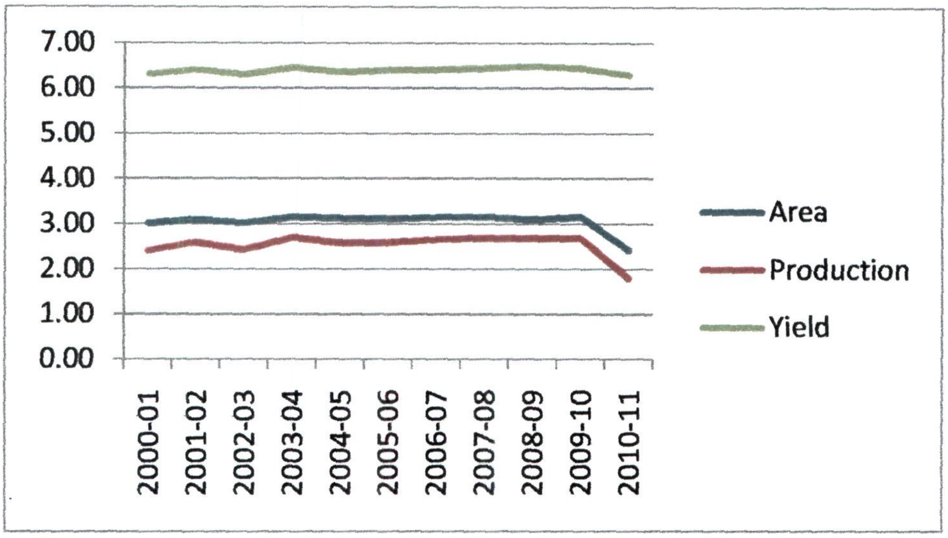
All India Area, Production and Yield of Total Pulses along-with coverage under Irrigation from 2000-01 to 2010-11

Year	Area Million Hectares	Production Million Tonnes	Yield Kg / Hectare	Area Under Irrigation (percent)
2000-01	20.35	11.08	544	12.5
2001-02	22.01	13.37	607	13.3
2002-03	20.50	11.13	543	14.4
2003-04	23.46	14.91	635	13.6
2004-05	22.76	13.13	577	13.9
2005-06	22.39	13.39	598	15.0
2006-07	23.19	14.20	612	15.4
2007-08	23.63	14.76	625	16.2
2008-09	22.09	14.57	659	NA
2009-10	23.35	14.60	625	NA
2010-11	11.16	18.24	537	NA

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2010-11) at www.agricoop.co.in

Figure- 4.4

Area, Production and Yield of Total Pulses from 2000-01 to 2010-11



According to table-4.4, the area under cultivation for total pulses was 20.35 million hectares while the production and yield was 11.08 million tonnes and 544 Kg per hectare respectively. This increased to 22.01 million hectares, 13.37 million tonnes and 607 Kg per hectare respectively in 2001-02. The area and production of total pulses goes to the maximum of 23.63 million hectares and 14.76 million tonnes respectively in 2007-08 and to the minimum of 11.16 million hectares and 6.00 million tonnes respectively in 2010-11. However the yield was maximum in 2008-09 i.e. 659 Kg per hectare and minimum in 2010-11 i.e. 537 Kg per hectare.

The area, production and yield of total pulses can be better understood with the help of line graph presented above in figure 4.4.

4.2.2 Impact of Climate Change on Rural Livelihoods

The climate change is already making impact on the lives of the population particularly the poor. Consistent warming trends and more frequent and intense extreme weather events such as droughts, cyclones, floods and hailstorms have been observed in recent decades. India has a large number of poor people. Poverty is related to the exposure of climate risks. The lives of the poor are affected by the risks and vulnerabilities that come with an uncertain climate. Climate change will gradually further increase their risks and vulnerabilities, putting pressure on already over-stretched coping strategies and magnifying inequalities based on gender and other disadvantages (UNDP, 2007).

There are well known losses due to impact of climate change on agriculture in the form of reduction in livelihoods and incomes of the people. However the adverse impact of climate change on human development is less understood and underestimated. The extreme climate events such as droughts, floods and cyclones can have devastating effects on human development. A climate shock affects livelihoods in many ways. They wipe out crops, reduce opportunities for employment, push up food prices and destroy property, confronting people with limited choices. The rich can cope up with these shocks through private insurance, by selling off assets, or by drawing on their savings. On the other hand, the poor reduce consumption, cut nutrition, take children out of school, or sell the productive assets on which their recovery depends. These are the choices that limit human capabilities and reinforce inequalities (UNDP, 2007).

Livelihoods can be affected adversely due to vulnerability in climate change for poor. It is widely asserted that the poor will be hardest hit by the impacts of climate change, especially those whose livelihoods are most heavily dependent on natural resources. The most vulnerable people will suffer more from climate change. Climatic hazards such as floods can badly affect the rural livelihood by damaging crops, houses, public utilities, cattle loss etc.. The magnitude of flooding has increased in recent decades. Floods have occurred almost every year since 1980 and were substantial in 2003 due to widespread rains, which affected even some of the most drought – prone areas. Flood damages in India in 2008 are given in the following table.

Table-4.5

Flood Damages in India

Flood Damages in India	2008	Maximum Damage	Year of Maximum damage
Affected area (million hectares-Mha)	3.55	17.50	1978
Population affected (millions)	41.46	70.45	1978
Damage to crops (Rs crores)	1,336.32	4,246.62	2000
Damage to houses (Rs crores)	1,011.97	1,307.89	1995
Damages to public utilities (Rs crores)	1,591.62	5,604.46	2001
Cattle Lost ('000)	71	618	1979
Human life lost (No.)	2,439	11,316	1977
Total damages to crops, houses and public utilities (Rs crores)	3,939.90	8,864.54	2000

Source: Central Water Commission (2010), Water and Related Statistics.

As shown in the above table-4.5, the flood affected area in 2008 was 3.55 Mha, while the maximum affected area was 17.50 Mha in 1978. Population affected due to flood in 2008 was 41.46 millions while it was maximum in 1978 i.e. 70.45 millions. Damage to crops due to flood in 2008 was of 1336.32 crores which hardly hit the rural poors. However the damage to crops was maximum of 4246.62 crores in 2000. The cost of flood damaged houses was 1011.97 crores in 2008 and 1307.89 crores in 1995 which was maximum. The maximum damage to public utilities was of 5604.46 crores in 2001. Cattle loss was 71 per 1000 in 2008 and 618 per 1000 in 1979. Human life loss was 2439 in 2008 and 11316 in 1977 due to flood. In addition, epidemics in the aftermath of flood events are also responsible for considerable loss of human lives.

Rural households tend to rely heavily on climate-sensitive resources such as local water supplied and agricultural land, climate sensitive activities such as arable farming and livestock husbandry, and natural resources such as fuelwood and wild herbs (Shackelton & Shackelton). Climate change can reduce the availability of these local natural resources, limiting the options for rural households that depend on natural resources for consumption or trade. Land may become less fertile, fewer needs may be available for basket making; there may be less local fuelwood for cooking. People whose adaptive capacity is constrained, will experience the negative effect on yields of low-latitude crops, combined with a high vulnerability to extreme events (FAO, 2010).

Men and women are affected differently in all phases of climate-related extreme weather events. Many of the world's poorest people are women living in rural areas in developing countries who are currently dependent on subsistence agriculture to feed their families and who are disproportionately affected by the lack of modern fuels and power sources for farming, household maintenance and productive enterprises (FAO, 2010). Women in poor households are especially vulnerable on all these counts with few resources for adoption.

Of course, shifts in climate will bring different changes to different regions. For instance some areas may see greater natural resources because of increased rainfall. But on balance, the poorest regions are most likely to suffer because they are least able to adjust to new conditions.

4.3 Climate Change, Food Security and Rural Poor

India is a large developing country with nearly 55 percent of the population depending directly on the climate sensitive sectors such as agriculture, fisheries and forests. Climate change is likely to have implications on food production, water supply, biodiversity and livelihoods. A large part of the Indian agriculture depends on monsoon so that the fluctuations can be seen in the market of agriculture and essential commodities due to early or delayed arrival of monsoon. Any change in country's rainfall pattern impacts agriculture and hence the country's economy and food security.

The Food and Agriculture Organization (FAO, 2002) defines food security as "a situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe and nutritious food that meets their dietary need and food preferences for an active and healthy life". To have enough diet is a basic right of every human. But in India, presently food security is insecure and it may perhaps collapse in future. This is because food is not available with the recommended quantity of nutrients and the number of undernourished people is rising every year (Gahukar, R.T., 1994).

According to the estimates of the International Food Policy Research Institute, additional 38 percent rice should be produced by 2025 to assure the growing demand. The agricultural land supplies nearly 90 percent of human food requirements and the food production have increased by about sevenfold during the last century (Ramana, A.V., 2008). Although, with the modern technologies and progression in science, human-being has achieved control on many factors such as soil, seed, fertilization and plant protection but the control on weather is still not achieved, it is still a key factor in agricultural efficiency (Prajapati Minaxi R., 2011).

Since, agriculture is not only a source of the commodity food but also a source of income, therefore it is essential to trim down the impact of agriculture on environment. Short duration of the growing period, decrease in water availability and poor verbalization are likely the causes of decline in the potential yields. Agricultural production such as textile products, medicinal plants, horticulture, forest revenues, dairy by-products and other globally traded produce sustain the economy of the nation (Selwaraj, A., and Maheswari, T., 2008).

4.3.1 Impact of climate change on Food Security

Food security is related to climate change both directly and indirectly. Crops production and growth is governed by climate parameters. Any change in temperature and humidity will have a direct impact on the quality of food produced. Indirect linkages pertain to catastrophic events such as floods and droughts which are projected to multiply as consequences of climate change leading to huge crop loss and leaving large patches of arable land unfit for cultivation, and hence threatening for food security (Chaudhry Anita. Aggarwal P.K., 2007). Further, climate change and food security are also related because climate change can directly affect a country's ability to feed its people, but all countries are not equally affected. The performance of India's foodgrains production is given in the following table-4.6.

Table-4.6

Season-wise Area, Production and Yield of Foodgrains from 1990-91 to 2009-10

Year	Kharif			Rabi			Total		
	A	P	Y	A	P	Y	A	P	Y
1	2	3	4	5	6	7	8	9	10
1990-91	80.78	99.44	1231	47.06	76.95	1635	127.84	176.39	1380
1991-92	78.02	91.59	1174	43.85	76.79	1751	121.87	168.38	1382
1992-93	77.92	101.47	1302	45.23	78.01	1725	123.15	179.48	1457
1993-94	75.81	100.40	1324	46.94	83.86	1787	122.75	84.26	1501
1994-95	75.19	101.09	1344	48.67	90.41	1858	123.86	191.50	1546
1995-96	73.60	95.12	1292	47.42	85.30	1799	121.02	180.42	1491
1996-97	75.34	103.92	1379	48.24	95.52	1980	123.58	199.44	1614
1997-98	74.15	101.58	1370	49.70	90.68	1825	123.85	192.26	1552
1998-99	73.99	102.91	1391	51.18	100.69	1967	125.17	203.60	1627
1999-00	73.24	105.51	1441	49.87	104.29	2091	123.11	209.80	1704
2000-01	75.22	102.09	1357	45.83	94.73	2067	121.05	196.81	1626
2001-02	74.23	112.07	1510	48.55	100.78	2076	122.78	212.85	1734
2002-03	68.56	87.22	1272	45.30	87.55	1933	113.86	174.77	1535
2003-04	75.44	117.00	1551	48.01	96.19	2004	123.45	213.19	1727
2004-05	72.26	103.31	1430	47.82	95.05	2004	120.08	198.36	1652
2005-06	72.72	109.87	1511	48.88	98.73	2020	121.60	208.60	1715
2006-07	72.67	110.58	1522	51.04	106.71	2091	123.71	217.28	1756
2007-08	73.56	120.96	1644	50.51	109.82	2174	124.07	230.78	1860
2008-09	71.43	118.14	1654	51.40	116.33	2263	122.83	234.47	1909
2009-10	69.33	103.84	1498	52.04	114.36	2197	121.37	218.20	1798

A – Area (in Million Hectares)
P – Production (in Million Tonnes)
Y – Yield (in Kg./Hectare)

Source: Directorate of Economics and Statistics, Department of Agriculture and Cooperation (2010-11) at www.agricoop.co.in

Figure- 4.5

Area, Production and Yield of Kharif Crops from 1990-91 to 2009-10

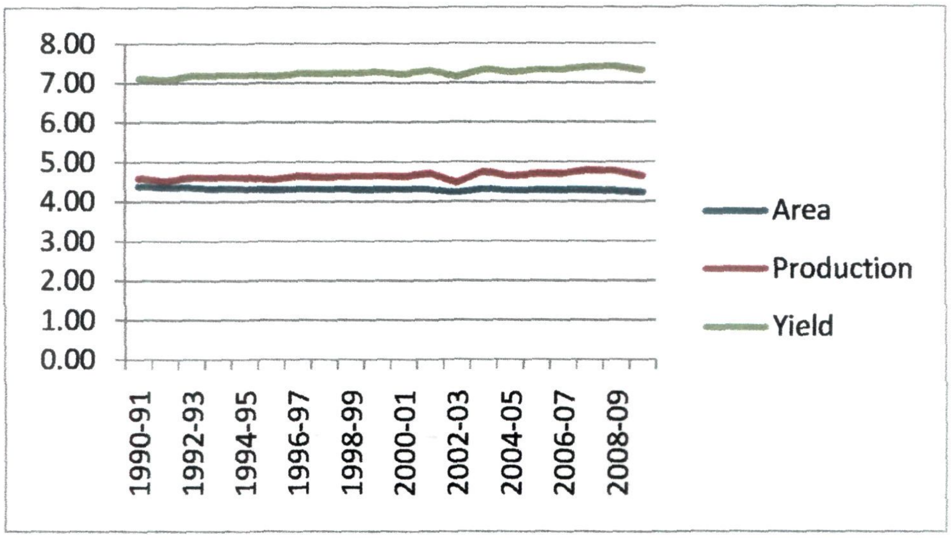


Figure- 4.6

Area, Production and Yield of Rabi Crops from 1990-91 to 2009-10

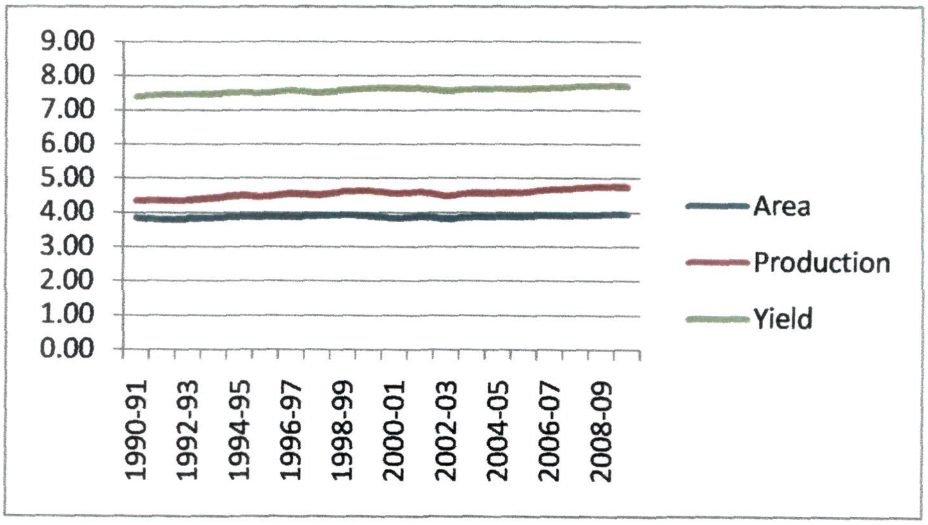
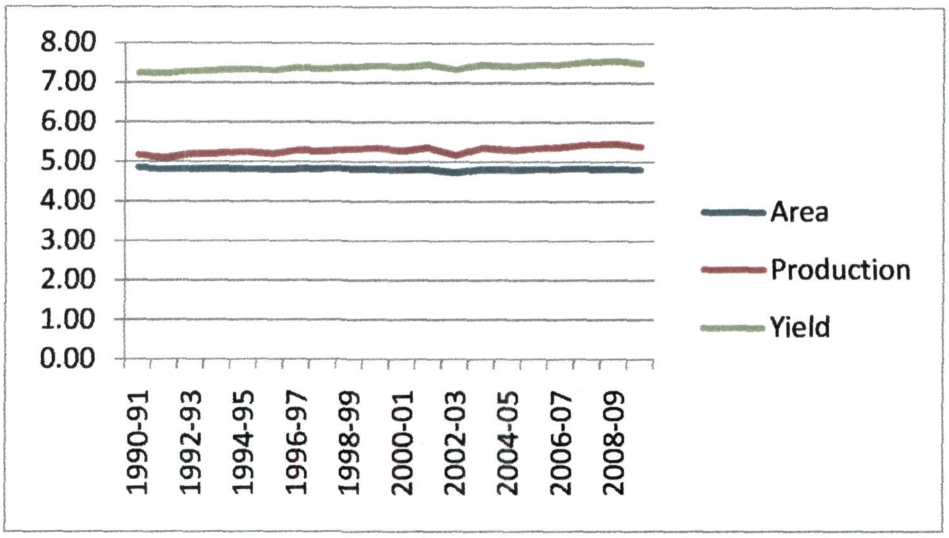


Figure- 4.7

Area, Production and Yield of Total Foodgrains from 1990-91 to 2009-10



The above table-4.6 provides the area (in million hectares), production (in million tonnes) and yield (in Kg per hectare) of foodgrains during Kharif and Rabi season from 1990-91 to 2009-10.

According to the table, in 1990-91, the area under cultivation for Kharif crops was 80.78 million hectares and the production and yield was 99.44 million tonnes and 1231 Kg per hectare respectively. But the area under cultivation for Rabi crops was 47.06 million hectares which is much less than that of Kharif crop. Production of Rabi crops was 76.95 million tonnes and yield was 1635 Kg per hectare during that same year. After this year there is a continuous fall in the area, production and yield of both the seasons and it goes to the minimum of 68.56 million hectares area, 87.22 million tonnes production and 1272 Kg per hectare yield during the Kharif season in the year 2002-03 and during the Rabi season it was the minimum of 45.30 million hectares, 87.55 million tonnes and 1933 Kg per hectare respectively in the same year 2002-03. All these slightly increases to 69.33 million hectares, 103.84 million tonnes and 1498 Kg per hectare respectively in 2009-10 for Kharif season and 52.04 million hectares area, 114.36 million tonnes production and 2197 Kg per hectare yield for Rabi season. The fluctuations can be seen in the entire table during both the seasons.

The area, production and yield of Kharif crops, Rabi crops and Total Foodgrains can be better understood with the help of line graph shown in above figure 4.5, figure 4.6 and figure 4.7.

Indian climate is very much suitable for the cultivation of most of the crops in different parts of our country because of large scale variations in the climate across the region. But Indian soil is most suited for the cultivation of foodgrains particularly Wheat and Rice.

The production of wheat is done in the Rabi season when the rainfall is limited. Because of this season the production of wheat found mainly in Punjab, Haryana and Western Uttar Pradesh where there is availability of assured irrigation. Since wheat production is heavily dependent upon assured irrigation, therefore a change in temperature is expected to affect the production of wheat.

Rice is a major crop of Kharif season in which irrigation is required in larger quality that is available in India during this season through the monsoon. A continuous rain throughout the season also maintains the temperature fluctuations. Therefore climate change is supposed to have more effects on crops during the season not only through changes in quantity and pattern of precipitation but also from changes in temperature. This can be easily analyzed from the above table-4.6.

The effect of climate change can be easily seen from the fact that there is a large scale fluctuation in the area under cultivation in the Kharif season. It can be easily seen that when area under cultivation has fallen it has reduced the total production as well as productivity and given a clear cut indication that climate change has played a very important role in the cultivation of crops during the crops season.

In comparison to the Kharif season the fluctuation in the area under cultivation in Rabi season is low that may be caused by the availability of assured irrigation facilities. The fluctuation in the production as well as productivity is also realized along with the fluctuation in the area under cultivation.

The same result can be found out in case of total foodgrains production. A change in area under cultivation is always accompanied by change in production and yield of the foodgrains. It can therefore be said that the factors which are responsible for the change in area under cultivation are also responsible for production and yield of the crops in which the climate change is the most important and dominating.

Food security is not narrowly defined as whether food is available, but whether the monetary and non-monetary resources at the disposal of the population are sufficient to permit everyone access to enough quantities and qualities of food (Schmidhuber and Tubiello, 2007). Climate change affects all four dimensions of food security i.e. food production and availability, stability of food supplies, access to food, and food consumption (IPCC, 2007).

Climate significantly affects food production directly through changes in agro-ecological conditions and indirectly by affecting expansion and distribution of incomes, and thus insists for agriculture produce. Climate conditions are projected to become patchier than at present, with increasing frequency and severity of extreme events. Stability of food supplies and food security can adversely affect by variations in crop yields and local food supplies. Climatic fluctuations will be most marked in semi-arid and sub-humid regions and are likely to reduce crop yields, livestock numbers and productivity.

Access to food refers to the capacity of individuals, communities and countries to acquire food in adequate quantities and quality. Over the last 30 years decrease in real prices for food and increase in real incomes have led to considerable improvements in access to food in many developing countries. Increase in food price and decrease in rate of income growth resulting from climate change may overturn this trend. Climate change may start a vicious circle where communicable diseases, including water-borne diseases, cause or compound hunger, which in turn, makes the affected population more vulnerable to those diseases. Results may include declines in food consumption and an increase in poverty, morbidity and mortality rates.

Food security will depend not only on climate and socio-economic impact on food production, but also on economic growth, changes to trade flows, stocks and food aid policy. Thus, the direct impact of climate change on agriculture and food supply which includes shortage in grain production resulting in less availability of food, especially to the economically poor people. The yield per hectare of major crops is given in following table-4.7.

Table-4.7

Yield per Hectare of Major Crops from 1950-51 to 2009-10

CROP	1950-51	1960-61	1970-71	1980-81	1990-91	2000-01	2009-10
Rice	668	1,013	1,123	1,336	1,740	1,901	2,130
Wheat	655	851	1,307	1,630	2,281	2,708	2,830
Jowar	353	533	466	660	814	764	911
Bajra	288	286	622	458	658	688	728
Maize	547	926	1,279	1.159	1,518	1,822	2,002
Pulses	441	539	524	473	578	544	625
Total Foodgrains	552	710	872	1,023	1,380	1,626	1,798
Oilseeds	481	507	579	532	771	810	955
Cotton	88	125	106	152	225	190	395
Jute	1,043	1,049	1,186	1,245	1,833	2,026	2,358

Sources:

(i) Economic Survey, 1980-81, (Delhi, 1981), Statement 17, p. 77;
(ii) Economic Survey, 2007-08, (Delhi, 2008), Appendix Table 1.14, p. A-19; and
(iii) Economic Survey, 2010-11, (Delhi, 2011), Appendix Table 1.14, p. A-19.

Table-4.7 gives increase in yield per hectares of Major crops. The table shows that over the period 1950-51 to 2009-10, yield per hectare of all foodgrains has increased by more than three times from 552 Kg per hectare in 1950-51 to 1789 Kg per hectare in 2009-10. Most significant increase has been recorded by wheat with its yield increasing from 655 Kg per hectare in 1950-51 to as high as 2830 Kg per hectare in 2009-10. As far as coarse cereals are concerned, while the productivity of maize has increased significantly, during recent years, the productivity of jowar and bajra has increased relatively slowly. Moreover, there is wide yearly fluctuation. Most disappointing has been the performance of pulses. In fact, productivity of pulses in 2000-01 was at the same level as 1960-61 even after four decades. However, the productivity rose somewhat to 625 Kg per hectare in 2009-10.

India is home to the largest numbers of hungry and deprived people in the world. Despite fast economic growth and piling food stocks in the government godowns, India has 360 million undernourished and 300 million poor people. Sustaining supply of food itself is emerging as a critical issue. There is a decrease in the growth of food grain production in the last few decades. During 1996-2008, it increased by just 1.2 percent per annum from 199 to 230 million tonnes, as against an annual rate of growth of 3.5 percent achieved during the 1980s (UNDP, 2009).

The poor people lack purchasing power. This led to artificial surplus in food grains stock and enabled government to export an average of about seven million tonnes food grains annually during 2002-2008. The net food grains availability has declined from 510 grams per day per capita in 1991 to 443 grams per day per capita in 2007 (UNDP, 2009). As the poor have little access to the more expensive fruits, vegetables, poultry and meat products, so they are the most affected. They need food but don't have purchasing power. This situation is more pronounced in central and eastern India.

4.4 Climate Change and Access to Safe Water

"Water is life's mater and matrix, mother and medium. There is no life without water", a famous quote which highlights the importance of water and its value in sustenance of life on earth. UNICEF report on Indian water says, "there will be constant competition over water, between farming families and urban dwellers, environmental conservationists and industrialists, minorities living off natural resources and enterpreneurs seeking to commodify the resources base for commercial gain" (G. Anand, 2005).

More than two billion people worldwide are facing water scarcity (D. Celia, 2006) and this is particularly a crisis in India. Currently millions of Indians lack access to safe water and day by day this situation is getting worse. In terms of population, India occupies second position in the world and is expected to be on first position by 2050 when it reaches 1.6 billion (BBC news). As the number of people grows there is an increase strain on water resources. Thus, a rapidly growing economy and a large agricultural sector make India's supply of water thinner.

Climate change is expected to exacerbate the problem by causing erratic and unpredictable weather, which could drastically diminish the supply of water coming from rainfall and glaciers. Earlier, water was considered to be an endless natural resource, but lately due to climate change and endless pollution the whole world is facing a looming water crisis. Water resources have started depleting across the world due to climate changes which have been released due to uncontrolled and unreasonable human activities. India is likely to face problems such as food shortages, intrastate, and international conflict because of increase in demand for water which out-ship the supply of water by increasing amounts in coming years.

The per capita average annual water availability in the country is reducing arithmetically due to increase in population. The average annual per capita availability of water in the country taking into consideration the population of the county as per the 2001 census, 2011 census and the population projections for the year 2025 and 2050 is as here under:

Table-4.8

Average Annual Per Capita Availability of Water in India

Year	Population (Million)	Per capital Average Annual Availability (m3/year)
2001	1029 (2001 census)	1816
2011	1210 (2011 census)	1545
2025	1394 (Projected)	1340
2050	1640 (Projected)	1140

Source: Central Water Commission (2011), Water and Related Statistics.

The per capita water availability figures given in the above table-4.8 are the national average figures while the position is quite different in the individual river basins. As given in the table, according to 2001 census, the population of the country was 1029 millions in 2001 and per capita average annual availability of water was 1816 cubic meters. In 2011, the population was 1210 millions according to 2011 census and per capita average annual availability was 1545 cubic meters. The projected population in 2025 and 2050 is 1394 millions and 1640 millions respectively. While the projected average annual per capita water availability are 1340 cubic meters and 1140 cubic meters respectively.

A per capita availability of less than 1700 cubic meters is termed as a water – stressed condition while per capita availability below 1000 cubic meters is termed as a water – scarcity condition.

India's climate is not particularly dry, nor it is lacking in rivers and ground water but the supply of water is diminished due to poor management, government corruption, unclean laws, and industrial and human waste. The available water is practically useless due to huge quantity of pollution. Thus, the water crisis in India is a manmade problem. The Indian government must balance the competing demands between urban and rural, rich and poor, the economy and the environment, while managing the water resources.

4.4.1 Demand for Water

India used approximately 829 billion cubic meters of water every year amongst the domestic, agricultural, and industrial sector, which is expected to double its demand and consequently exceed the 1.4 trillion cubic meters of supply (Somni Sengupta, 2006). Total water requirement of the country for different uses as assessed by National Commission on Integrated Water Resource Development (NCIWRD) – 1999 is given below.

Table-4.9
Total Water Demand for Different Uses (in BCM) in India

Uses	Year 1997-98	Year 2010	Year 2025	Year 2050
Irrigation	524	557	611	807
Domestic	30	43	62	111
Industries	30	37	67	81
Power	9	19	33	70
Inland Navigation	0	7	10	15
Environment Ecology	0	5	10	20
Evaporation Losses	36	42	50	76
Total	**629**	**710**	**843**	**1180**

Source: National Commission on Integrated Water Resource Development (NCIWRD) – 1999.

The above table-4.9 shows the demand for water in different sectors mainly Irrigation, Domestic, Industries, Power, Inland Navigation, Environment Ecology and Evaporation Losses. The demand of water is given for the year 1997-98 and 2010 as 524 BCM and 557 BCM respectively for irrigation sector, 30 BCM and 43 BCM for domestic, 30 BCM and 37 BCM for industries, 9 BCM and 19 BCM for power or energy and 36 BCM and 42 BCM for evaporation losses for the year 1997-98 and 2010 respectively.

The table-4.9 also shows that the projected demand for water for the year 2025 and 2050 respectively is 611 BCM and 807 BCM for irrigation, 62 BCM and 111 BCM for domestic, 67 BCM and 81 BCM for industries, 33 BCM and 70 BCM for power, 10 BCM and 15 BCM for inland navigation, 10 BCM and 20 BCM for environment ecology and for evaporation losses it is projected as 50 BCM for the year 2025 and 76 BCM for 2050. The total demand for water in 1997-98 was 629 BCM and in 2010 it was 710 BCM. And the total demand for water in 2025 will be 843 BCM and 1180 BCM in 2050 as projected by NCIWRD.

In India's domestic sector, 1.1 billion people need access to clean drinking water. The demand for drinking water comprises about 4-6 percent of total water demand between the urban and rural populations. Due to the useful and desirable features of cities, such as flush toilets and washing machines, people living in urban areas live more water intensive lives. The urban population has doubled over the past 30 years, now representing 30 percent of India's total population (World Bank Report, 2005) and is expected to reach 50 percent of the total population by 2025 (www.dnaindia.com).This increase in population accelerate the water crisis in India, especially when more and more people move into the cities and become part of the middle class. As the government is unable to deliver fresh water to the cites, the urban people fulfill their needs from ground water because the rivers are too polluted to drink. This results in the depletion of underground aquifers. Rural citizens face a similar crisis. Currently 30 percent of the rural populations lack access to drinking water, and of the 35 states in India, only 7 have full availability of drinking water for rural inhabitants (UNICEF, 2002). People in rural areas demand less water for day to day living than those in urban areas. The majority of their water demand comes for agricultural needs.

India's agricultural sector currently uses about 90 percent of total water resources (UNICEF, 2002). Irrigated agriculture caused ground water depletion. Due to water pollution in rivers, India draws 80 percent of its irrigation water from groundwater (World Bank Report, 2005). The availability of canal water led farmers to adopt highly profitable, but extremely water intensive crops, such as sugarcane (Tribune India, 2005). In addition, India achieved its goal of obtaining food security. The rural economy sustains two-thirds of India's 1.1 billion citizens (G. Anand, 2005). If India wants to maintain its level of food security, farmers will have to switch to less water intensive crops.

4.4.2 Supply of Water

In India, the supply of drinking water continues to be inadequate, despite longstanding efforts by the various levels of government and communities at improving coverage. The sources of India's water supply are surface water and groundwater. The main rivers, which are the sources of surface water, are the Ganges, Brahmaputra, Mahanadi, Godavri, Kaveri, Indus, Narmada, and Tapti which flow into the Bay of Bengal and Arabian Sea. India receives an average of 4,000 billion cubic meters of rainfall every year. But only 48 percent of rainfall ends up in India's rivers. Out of this only 18 percent can be utilized due to lack of storage (UNICEF, 2002). In the monsoon season, June to September, India receives rainfall, on average, 75 percent of its total annual precipitation. The government is unable to store surplus water for the dry season due to India's storage. Thus, the supply of cities that depend on surface water is threatened by pollution, increasing water scarcity and conflicts among users.

Table-4.10

Water Resources Potential of River Basins of India

River Basin	**Catchments Area (Sq. Km)**	**Average Water Resources Potential (BCM)**
Indus	321289	73.3
Ganga-Brahmaputra-Meghna		
a. Ganga	861452	525
b. Brahmaputra	194413	537.2
c. Barak & others	41723	48.4
Godavari	312812	110.5
Krishna	258948	78.1
Cauvery	81155	21.4
Subernarekha	29196	12.4
Brahmani-Baitarni	51822	28.5
Mahanadi	141589	66.9
Pennar	55213	6.3
Mahi	34842	11
Sabarmati	21674	3.8
Narmada	98796	45.6
Tapi	65145	14.9
West Flowing Rivers from Tapi to Tadri	55940	87.4
West Flowing Rivers from Tadri to Kanyakumari	56177	113.5
East Flowing Rivers between Mahanadi and Pennar	86643	22.5
East Flowing Rivers between Pennar & Kanyakumari	100139	16.5
West Flowing Rivers of Kutuh and Saurashtra including Luni	321851	15.1
Minor Rivers Draining into Myanmar (Burma) and Bangladesh	36302	31
Total		**1,869.4**

Source: Central Water Commission (1993), Water and Related Statistics.

Of the many rivers in India, 12 are classified as major rivers whose total catchments area is 252.8 million hectares (Mha). Among the major rivers, the Ganga – Brahmaputra – Meghna system is the biggest with a catchment area of about 110 Mha as given in above table-4.10. The other major rivers along with their catchment areas are Indus (32.1 Mha), Godavari (31.3 Mha), Krishna (25.9 Mha), Cauvery (8.1 Mha), Mahanadi (14.2 Mha), Pennar (5.5 Mha), Brahmani – Baitarni (5.2 Mha), Mahi (3.5 Mha), Sabarmati (2.2 Mha), Narmada (9.9 Mha) and Tapi (6.5 Mha). The catchment area of medium rivers is about 25 Mha.

The average annual water resources potential in the country was assessed at 1869.4 BCM. The Average Water Resources Potential of 12 major rivers given in table-4.10 above is Indus (73.3 BCM) Ganga – Brahmaputra – Meghna (1110.6 BCM), Godavari (110.5 BCM), Krishna (78.1 BCM), Cauvery (21.4 BCM), Mahanadi (66.9 BCM), Pennar (6.3 BCM), Brahmani – Baitarni (28.5 BCM), Mahi (11 BCM), Sabarmati (3.8 BCM), Narmada (45.6 BCM) and Tapi (14.9 BCM). The average water resource potential of medium and small rivers is 298.4 BCM.

Groundwater is the major source of drinking water in both urban and rural India. It is also an important source of water for the agricultural and the industrial sectors. India possesses about 432 BCM of groundwater replenished yearly from rain and river drainage, but only 395 BCM are utilizable. Of that 395 BCM, 82 percent goes to irrigation and agricultural purposes, while only 18 percent is divided between domestic and industrial sector (IBID). Groundwater is increasingly being pumped from lower and lower levels much faster than rainfall is able to replenish it. The number of wells drilled for irrigation of both food and cash crops have rapidly and indiscriminately increased (World Bank Report, 2005). Groundwater crisis is not the result of natural factors, it has been caused by human actions.

Climate change is further worsening the depleting supply of water. Glaciers in the Himalayas and the Tibetan Plateau have been melting due to warm climate. According to the IPCC, global temperatures have warmed by 0.76 °C over the last 100 years (Solomon, S., D. Qin, et.al., 2007). As a result, flooding increased initially, especially during the monsoon season when rainfall is already at its heaviest. However, in subsequent years, there will be less and less glacial melt water to continuously supply India's rivers. Nearly 70 percent of discharge to the river Ganges comes from Napalese snow-fed rivers, which means that if Himalayan glaciers dry up, so could the Ganges (Navin Singh Khadka, 2006). The Ganges has numerous tributary rivers which supply water to hundreds of millions of people across India. Therefore if the Ganges even partly dried up, it would have drastic consequences for a huge population.

4.4.3 Access to Water

In India, 88 percent of the population had access to an improved water source in 2008 (UNICEF/WHO, 2010). In rural areas, where 72 percent of India's population lives, 84 percent had access to improved water while the share is 96 percent in urban areas. Access to water has improved substantially since 1990 when it was estimated to stand at 72 percent (UNICEF/WHO, 2010). According to Indian norms, access to improved water supply exists if atleast 40 liters per capita per day of safe drinking water are provided within a distance of 1.6 km or 100 meter of elevation difference. There should be atleast one pump per 250 persons.

In 2010, Thiruvanathapuram and Kota, only these two cities get continuous water supply in India (V. Srinivasa, 2010). In 2005, despite generally sufficient infrastructure none of the 35 Indian cities with a population of more than one million distributed water for more than a few hours per day. A 2007 study by the Asian Development Bank showed that in 20 cities the average duration of supply was only 4.3 hours per day (ADB, 2007). None of the 20 Cities had continuous supply. The longest duration of supply was 12 hours per day in Chandigarh and the lowest was 0.3 hours per day in Rajkot (ADB, 2007).

The accessibility of drinking water at household level has many aspects like the distances traveled by member of a household to reach the source of drinking water, households getting good quality of drinking water, daily supply of water in household etc. The quality of drinking water is a very important component in maintaining good health of the population. Many households attempt to improve the quality they drink by adopting various methods for treating the water before drinking. The following table provides the number per 1000 households getting good quality of drinking water during 2012.

Table-4.11

Number per 1000 Households Getting Good Quality of Drinking Water During 2012

State/UT	Rural	Urban
Andhra Pradesh	880	932
Arunachal Pradesh	911	829
Assam	580	638
Bihar	801	850
Chhattisgarh	905	901
Delhi	942	900
Goa	897	723
Gujarat	941	831
Haryana	924	771
Himachal Pradesh	945	887
Jammu & Kashmir	780	656
Jharkhand	899	839
Mizoram	999	1000
Nagaland	944	971
Orissa	873	914
Punjab	849	729
Rajasthan	806	871
Sikkim	941	964
Tamil Nadu	865	884
Tripura	793	846
Uttarakhand	944	856
Uttar Pradesh	922	870

West Bengal	821	889
Andaman & Nicobar Island	849	837
Karnataka	938	919
Kerala	947	902
Madhya Pradesh	908	885
Maharashtra	941	926
Manipur	948	993
Meghalaya	943	965
Chandigarh	901	847
Nagar Haveli	952	1000
Daman & Diu	985	989
Lakshadweep	957	878
Pondicherry	825	802
All India	877	881

Source: NSS 69th Round (July, 2012 - Dec, 2012): Key indicators of Drinking Water, Sanitation, Hygiene and Housing Condition in India.

The above table-4.11 shows that 87.7 percent and 88.1 percent households in rural India and urban India respectively were getting good quality of drinking water. The table shows that in rural areas of most of the bigger states, more than 75 percent of households got good quality of drinking water except in Assam (58.0 percent). Similarly in Urban areas of most of the bigger states more than 70 percent of households got good quality of drinking water except in Assam (63.8 percent) and Jammu and Kashmir (65.6 percent).

Many households had used piped water or tap water either as a principal source for drinking water, or as a supplementary source for drinking water, or as a principal source of water for other uses of the households. For these households, the frequency of water supply was ascertained. The following table shows the number per 1000 households who got daily supply of water during 2012.

Table-4.12

Number per 1000 Households who got Daily Supply of Water during 2012

State/UT	Rural	Urban
Andhra Pradesh	758	599
Arunachal Pradesh	793	873
Assam	908	923
Bihar	515	889
Chhattisgarh	1000	957
Delhi	419	970
Goa	738	946
Gujarat	780	817
Haryana	828	926
Himachal Pradesh	859	860
Jammu & Kashmir	855	855
Jharkhand	1000	964
Mizoram	547	21
Nagaland	677	333
Orissa	844	965
Punjab	981	962
Rajasthan	671	694
Sikkim	961	990
Tamil Nadu	798	642
Tripura	879	999
Uttarakhand	997	1000
Uttar Pradesh	883	964
West Bengal	963	979
Andaman & Nicobar Island	496	81
Karnataka	1000	998
Kerala	622	843

Madhya Pradesh	626	593
Maharashtra	619	852
Manipur	418	355
Meghalaya	999	886
Chandigarh	1000	998
Nagar Haveli	1000	1000
Daman & Diu	325	817
Lakshadweep	760	1000
Pondicherry	1000	995
All India	753	781

Source: NSS 69th Round (July, 2012 - Dec, 2012): Key indicators of Drinking Water, Sanitation, Hygiene and Housing Condition in India.

At all India level, it is estimated that 75.3 percent of such rural households and 78.1 percent of such urban households received daily supply of water. According to the table-4.12, among rural areas of bigger states, Chhattisgarh (as well as Jharkhand) had the highest (100.0 percent) and Bihar, lowest (51.5 percent) proportion of such households getting daily supply of water throughout the year. Similarly among urban areas of bigger states, Uttarakhand had the highest (100.0 percent) and Karnataka, the lowest (46.1 percent) proportion of such households getting daily supply of water throughout the year.

An immediate solution to India's water crisis is to change water management practices by regulating usage with effective legislation. Historically, water has been viewed as an unlimited resource that did not need to be managed as a scarce commodity or provided as a basic human right. These attitudes are changing in India, there is a growing desire for decentralized management developing, which would allow local municipalities to control water as best needed for their particular region.

4.5 Implications Of Climate Change On Rural Poor

India is well known for the lands of rural dominance with largest chunks are living in the sub-urban and rural villages. These households are heavily relying on climate-sensitive resources such as local water availability, agricultural land, arable farming, livestock husbandry, fuelwood and wild herbs. The availability of natural resources gives an ease of life to the rural poor. The limitations of these resources are reducing the available options in front of rural poor, which depend on natural resources for consumption of trade and livelihoods. Climate changes are diminishing the availability of these resources and open manifold risk to the rural poor. The key risks are reductions in food security, agricultural productivity and water availability. The outcomes of these risks are decreasing the earning potential of rural poor and increase their exposure towards diseases and other health related risks.

Generally, Climate changes have exposed the rural poor towards environment risks, reducing livelihoods possibilities and creating stress to the social institutions. The impacts of these risks are historically familiar mechanisms for rural poor, and for which rural poor have often developed a rich repertoire of adaptation strategies and practices. The rural populations have historically faced the environmental risks and develop themselves to counter these risks. The rural are practicing the adaptation strategy of personal and institutional capacity to safeguard their interest with external interventions. The aim is to understand the adaptation of policy and inquire them, for generating efficient coordination and giving fruitful solution to the rural poor.

The rural poor require fiscal and financial measures to survive under the risky environment. In the broader sense the impact of the climate change can be discussed by two approaches. First approach shows the 'potential impact' of climate change on different areas and other is to improve 'adaptive capacity' to counter the emerging challenges and achieving sustainability in the long run. In the process of potential impact the rural poor have different exposures and sensitivity. These exposures can be change in rainfall or/and temperature or/and precipitation, flood frequency, soil fertility etc. The sensitivity of rural poor is their population density and water stress (drinking and irrigation water). These exposures and sensitivity can be handled by improving adaptive capacity of the country. The adaptive capacities can be socio-economic, infrastructure, financial and governance capacities. To strengthen the adaptive capacity of the rural poor, therefore, governments and other external actors need to strengthen and take advantage of already existing strategies that many households and social groups use collectively or singly. The benefit of the adaptive capacity will generate employment, strengthen education, increase income and improve standard of living. The identification of actual exposures availability and the sensitivity analysis are major task to complete. The demographic dividend can be used to inculcate the adaptability.

Some of the impact and adaptation in the light of fiscal and financial measures as provided by Turpie and Visser (2013/14) is given below:

1. **Reduction in Water Supply (Quantity and Quality):** The Adaptation Actions include supply and sanitation infrastructure, supply management and demand management. Fiscal and Financial Measure to be taken are Grant, public-private partnerships, subsidies to motivate technological innovation, tradable water use rights and pollution permits, payments for ecosystem services, and water pricing.

2. **Declining Land and Renewable Resource Capacity:** The adaptation actions should be changes in farming practices, improved natural resource conservation measures and increased alternative livelihood opportunities. The measures include spatial planning of rural agriculture development/land reform, subsidized drought-resistant seeds, funding of extension services, improved financial services (credit and insurance), support of joint ventures to farm on spatially separated areas. increased support to land reform projects, support of agricultural cooperatives, funding of buyout schemes and abattoirs to reduce stocking rates during drought, more investment in education in rural poor and reduced perverse incentives for employment on farms.

3. **Rise in Sea-Level, Storms and Floods:** Disaster risk management should be adapted. Municipal infrastructure grants for infrastructural protection measures and grants for investment in 'ecological infrastructure' (e.g. acquisition of land for buffer areas) should be the measures for this.

4. **Health Risk:** Increased preventative action and medical facilities should be enhanced. Major investment to eradicate climate-sensitive disease vectors

(already underway), investment in infrastructure and Food subsidies, maize subsidies, social grants must be the fiscal and financial measure for health risk.

5. **Over All Risks:** Research and monitoring of climate, ecosystem, and socio-economic parameters and capacity building must be the adaptation actions. The fiscal and financial measures include national academic research funding support to climate change projects (e.g. research on viability of new cultivars), funding of national monitoring programmes, salary top-ups or tax breaks to attract professionals to government and health care positions in rural areas, significant investment in school education, funding from private sector, research foundations, NGOs and donor funding.

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Chapter-5

Conclusion and Suggestions

CONCLUSION AND SUGGESTIONS

5.1 Conclusion

In this last chapter of the present study an overview of the previous chapters has been presented. This chapter explains that how the questions raised in hypotheses of the study have been answered with the help of the results obtained for the investigations done in the earlier chapters. In this section chapter wise conclusion of the present research problem is given.

The climate of a country largely determines the nature and characteristics of vegetation and crops. In India, agriculture plays a crucial role in overall economic and social well being of masses. So the number of factors such as global warming, changes in pattern of rainfall, rapidly rising levels of carbon dioxide, other green house gases in the atmosphere, area under foodgrain production etc. have direct effects on agriculture in the country.

The present research work starts with three objectives:

- First to know the changes in the climate profile of the country;
- Second to find out the effects of climate change on crop yield as well as the production of crops; and
- Third to identify current climate changes and their implications for agricultural system, rural livelihood and rural poor.

For realization of above objectives the following hypotheses are formed:

- There is a change in climate profile of the country;
- There is a decrease in crop yield as well as crop production due to changes in climate; and
- Climate change has much implication for agricultural system and rural poor.

The first hypothesis of this research is to access the change in climate profile. We have studied this change in the second chapter of this research problem and the result of this study has found that there is a change in climate profile.

The second chapter discusses the Climate of India. Though there are a large number of variables that comprise the climate of a region like rainfall, temperature, wind and wind's speed, pressure, vegetation, topography etc. but it is difficult to discuss all. Therefore only four variables namely rainfall, temperature, flood and drought are studied in this chapter.

The All India Rainfall Distribution from 2000-01 to 2012-13 for Monson season, Post-monsoon season, Winter season and Pre-monsoon season shows the changes in rainfall pattern during these years. The fluctuations can be seen during these periods for all the seasons. During monsoon season, rainfall goes to the maximum of 947.3 mm in 2003-04 and minimum to 689.8 mm in 2009-10. During post monsoon season, maximum rainfall was 153.2 mm in 2010-11 and minimum rainfall was 64.1 mm only in 2000-01. There is a very little rainfall during winter season. It was only 69.8 mm in 2004-05 which was recorded to be maximum and 16.2 mm 2000-01 as minimum. During pre-monsoon season, the rainfall goes to the maximum of 161.6 mm in 2003-04 and 90.3 mm in 2011-12 as minimum.

Change in temperature can be better understood if we see the average maximum and minimum temperature region wise. Western Rajasthan and Haryana are the hottest place in India where the maximum temperature goes up to 50^{0}C during summer. In Punjab also, the maximum temperature in summer reaches up to 47^{0}C. On the other hand the coolest place in India is Northeast India and much of North India where the temperature may fall as low as 0^{0}C during the coldest months. Also in Western Ghats the low temperature can fall below freezing point. In Haryana the temperature could be as low as 1^{0}C during winters.

Drought – prone regions of Andhra Pradesh and Maharashtra and flood – prone districts in Orissa are on the edge of climate tolerance limits. Poor and marginal farmers who own less than one acre of land mostly populate these regions. There is an, urgent need to evolve comprehensive climate resilience strategies that must factor in risk assessment, better water management, developing varieties that can do well in stressful conditions, and bringing about certain changes in agricultural practices.

In this way it can be said that there is change in the climate profile of India. The summer has become more hot and the winter colder. The incidences of drought and flood have also increased over the period of time. This clearly shows that our first hypothesis is true, i.e. the climate profile of India has changed.

The third chapter examines the effect of climate change on foodgrains production. In this chapter we have taken into consideration some of the main Rabi and Kharif crops namely Wheat, Rice, Maize, Jowar, Bajra, Barley, Ragi, Small Millets, Cereals, Coarse Cereals, Total Pulses and Total Foodgrains. We relate the production of these crops with respect to all India rainfall distribution during growing and harvesting periods of these crops and examine the impact of rainfall on their production. Crop wise result is presented below.

The production of wheat has increased in the past years from 69.68 million tonnes in 2000-01 to 93.90 million tonnes in 2011-12. Effect of both post-monsoon rainfall and winter rainfall has been seen on its production. There are fluctuations in the production of wheat with respect to the rainfall. With an increase in rainfall the production increases in 2001-02 to 72.77 million tonnes then decrease in 2002-03 to 65.76 million tonnes with a fall in rainfall. Again the production of wheat has increased to 72.15 million tonnes in 2003-04 and then decrease to 68.64 million tonnes in 2004-05 with an increase and decrease in rainfall respectively. After that it continuously increases to the maximum of 93.90 million tonnes as there is improvement in precipitation.

The production of rice has increased from 72.78 million tonnes in 2000-01 and goes to the maximum of 91.53 million tonnes in 2011-12 then decrease a little to 85.59 million tonnes in 2012-13. The production of rice is directly dependent on monsoon rainfall. The production was minimum in 2002-03 i.e. only 63.08 million tonnes because the rainfall during this year is low, i.e. 737.1 mm.

The production of Maize has been given for both the seasons (Rabi and Kharif). Maize is mainly a Kharif crop and its production in Kharif season is much more than in Rabi season. During Rabi season the production of maize is mostly affected by winter season rainfall during January and February which is a harvesting season of Rabi crops. The production of maize was maximum in 2008-09 i.e. 5.61 million tonnes in Rabi season. During Kharif season fluctuations has been seen in its production. It goes to the maximum of 16.64 million tonnes in 2010-11 whereas the production of Maize was minimum in 2002-03 i.e. 9.27 million tonnes. This fluctuation in production of this crop is along with the fluctuation in rainfall. Both have moved in the same direction.

Jowar is also grown in both Rabi and Kharif season. The production of Jowar is more in Kharif season as compared to Rabi season. During Rabi season, its production has increased from 2.97 million tonnes in 2000-01 and goes to the maximum of 4.19 million tonnes with rise in rainfall but then declines to 2.79 million tonnes in 2011-12 when a fall in rainfall is recorded. Its production is affected by both post monsoon and winter rainfall during Rabi season. During Kharif season, the production of Jowar was maximum in 2003-04 which was 4.84 million tonnes. But then goes to the minimum of 2.63 million tonnes in 2012-13. The fluctuations were seen in its production with respect to the fluctuation in rainfall of monsoon season.

The production of Barley has increased from 1.43 million tonnes in 2000-01 and goes to the maximum of 1.69 million tonnes in 2008-09 then slightly decreased to 1.61 million tonnes in 2011-12. The production was minimum in 2004-05 and 2007-08 i.e. 1.20 million tonnes which is same in both the years. The relationship between production of Barley and rainfall is mainly inverse. That is, when rainfall increases production decreases and vice-versa.

The production of Bajra in 2000-01 was 6.76 million tonnes and decreased a little to 6.60 million tonnes in 2012-13. However, it goes to the maximum of 12.11 million tonnes in 2003-04 and to the minimum of 4.72 million tonnes in 2002-03. The effect of rainfall has been clearly seen on its production. The production is also good in 2010-11 and 2011-12 i.e. 10.37 million tonnes and 10.05 million tonnes.

The production of Ragi in 2000-01 was 2.73 million tonnes which decreased to 1.32 million tonnes in 2002-03 and goes to the minimum of 1.65 million tonnes in 2012-13. Its production sometimes directly and sometimes inversely related with rainfall during monsoon season.

Small Millets has a very little contribution in total foodgrains production among Kharif crops. The maximum production was only 0.74 million tonnes in 2011-12, and the minimum was 0.38 million tonnes in 2009-10. Its production is affected by rainfall during monsoon season.

The production of cereals and monsoon rainfall has a direct relationship. The production of cereals was maximum in 2011-12 i.e. 123.79 million tonnes when rainfall was 899.9 mm. However the production was minimum is 2002-03 i.e. 83.07 million tonnes when rainfall was 737.1 mm.

Coarse Cereals is grown in both the seasons but it is mainly a Kharif crop. The production of Coarse Cereals in Rabi season was maximum in 2008-09 i.e. 11.49 million tonnes which is inversely related to rainfall of both post-monsoon and winter season. Whereas during Kharif season the production of coarse cereals was maximum in 2010-11 i.e. 33.37 million tonnes which is three times (approx) the maximum production during Rabi season. The production during Kharif season is directly affected by the monsoon rainfall. The minimum production of Coarse Cereals during Kharif season was 19.99 million tonnes in 2002-03.

The production of total pulses is more during Rabi season as compare to Kharif season. The production was directly affected by post monsoonal rainfall, that is, when rainfall increases production increase and vice-versa. The production of total pulses during Rabi season increases from 6.62 million tonnes in 2000-01 to 11.05 million tonnes in 2011-12. But if we see the rainfall, there is only a little increase from 64.1 millimeters in 2000-01 to 65.7 millimeters in 2011-12. However, there is only a little change in the production of total pulses during Kharif season. The production goes maximum to 7.12 million tonnes in 2010-11 and to the minimum of 4.20 million tonnes in 2009-10. The effect of rainfall has been clearly seen on its production.

The production of total foodgrains is mainly affected by the post monsoon rainfall during Rabi season. The production has increased from 94.72 million tonnes in 2000-01 and goes to the maximum of 127.50 million tonnes in 2011-12. Whereas during Kharif season the production was maximum in 2011-12 i.e. 129.94 million tonnes. However during both the seasons, Kharif and Rabi, the production was minimum in 2002-03, i.e. 87.55 million tonnes during Rabi season and 87.22 million tonnes during Kharif season. Therefore we can say that our second hypothesis has proved in the sense that climate change has its effects on the production of crops, though sometimes negative and sometimes positive.

Climate change is an ongoing process. Starving in both animals and human can be worse in the developing world. There is a two-way relationship between livestock production and environmental health. On the one hand, livestock contributes to climate change and other environmental problems, and at the same time livestock health and productivity can be adversely affected by these environmental upsets. Climate determines ecosystem health over time, but weather drives immediate outbreaks and disasters. Hence implications of climate change on different fields, connected with plant, animal and human life need to be studied in depth at different levels for early mitigation. The environmental impacts of animal production require more focused attention from international organizations, governments, producers and consumers on meat and dairy products.

Livestock production systems in India are mostly based on traditional knowledge, low cost agricultural residues and agro-byproducts leading to lower productivity. Livestock sector is facing newer challenges, like increased incidence of emerging and re-emerging animal diseases, vulnerability to exotic diseases, shortage of feed and fodder and need to increase production to meet demand for animal products etc. Many of these challenges would require an appropriate national strategy to address these with support of the State Governments. There is an urgent need to have a national policy to ensure faster growth of the livestock sector, increased productivity and creation of employment opportunities in rural areas, leading to poverty reduction.

The fourth chapter takes into consideration the impact of climate change on rural poor under three sections; first, Climate Change, Agriculture and Rural Livelihood; second, Climate Change, Food Security and Rural Poor; and third, Climate Change and Access to Safe Water.

Climate change has proved to be a major challenge for agriculture and livelihood of billions of people including the rural poor. People living in rural areas mostly depend on agriculture for their livelihood.

Livelihoods may have been affected adversely due to vulnerability to climate change for poor. Vulnerability is high for many areas and population in India. Livelihoods are more vulnerable in mountainous areas like Himalayas, arid and semi-arid areas, vast coastal areas in South and forest areas in the region. Poor and vulnerable groups are women, children, indigenous people, coastal dwellers and mountainous population. Indigenous population forms the most vulnerable group due to climate change.

Food security is directly or indirectly related to climate change. Any change in climatic parameters such as temperature and humidity which govern crops growth have a direct impact on the quality of food produced. Climate change affects all four dimensions of food security, namely food availability, access to food, stability of food supplies and food utilization. Importance of these four dimensions of food security will differ across regions and over time. The impact of climate change on food security is highly dependent on the overall socio-economic status of the country that it has accomplished as the effects of climate change set in.

The impact of observed changes in climate trends, variability and extreme events show that the crop yield in India has declined due to rising temperatures and extreme weather events. It is that the area under foodgrains production has fallen from 127.84 million hectares to 121.37 million hectares during the period from 1990-91 to 2009-10. The production registered an increase from 176.39 million tonnes to 218.20 million tonnes during the above period. The foodgrains production looked quite impressive in 2008-09, which was 234.47 million tonnes. However the country has to face major challenge to increase its food production to 300 million tonnes by 2020 in order to feed it's ever – growing population, which is likely to reach 1.30 billion by the year 2020. In order to meet this demand, the country's farmers need to produce more foodgrains by 2020.

The study also indicates that there is a large scale fluctuations in the area under the cultivation in the Kharif season. The area under cultivation in the Kharif season continuously fall from 80.78 million hectares in 1990-91 to 69.33 million hectares in 2009-10 due to fluctuations in rainfall and changes in the temperature pattern. It can be clearly seen that when area under cultivation has fallen it has reduced the production from 117.00 million tonnes in 2003-04 to 103.84 million tonnes in 2009-10. This indicates that climate change has played a very important role in the cultivation of crops during the crop season.

In comparison to the Kharif season the fluctuation in the area under cultivation in Rabi season is low that may be caused by the availability of assured irrigation facilities. The fluctuation in the production as well as productivity is also realized along with the fluctuation in the area under cultivation. The area under cultivation of Rabi season has increased from 47.06 million hectares in 1990-91 to 52.04 million in 2009-10. With the increase in the area under cultivation, the production has increased from 76.95 million tonnes in 1990-91 to 114.36 million tonnes in 2009-10. This shows that the vulnerability of Rabi crops to the climate change has reduced but still the climate change has its impact on the Rabi crops.

Apart from the above, climate change also affects the availability of water. There is evidence to suggest that water budget estimates may be seriously overestimating the availability of water in the country. The rivers and water bodies are already under tremendous pressure to meet the demands from various sector while maintaining their ecological integrity. Climate variability which is now a characteristic feature of the country is more pronounced than ever, challenging people's resilience and increasing pressure on water bodies.

The national per capita water resource availability has declined considerably over the years and of particular concern is the disparity in water footprints of the rich and the poor. The government and local communities have responded well to many imminent challenges but a paradigm shift in the way water is perceived as a resource will be required to build a forceful course of action.

The water needs in the country have risen exponentially to an unprecedented scale, especially in recent times. The demand has outstripped supply. Meeting the rising water demand is a pressing challenge that India currently faces. Demand side management has been put forward as a viable option but it requires strong political backed up by adequate infrastructural support. The solution to the problem in water across the country lies largely in areas of effective mechanism for conservation, distribution and efficient use and management of this resource.

Water quality issues are immensely important concerns from human health and ecological status. The study clearly establishes that water quality issues in India have reached or even passed the critical stage. It also reveals that while increasing access to water is crucial, doing so without addressing quality issues may prove to be a pointless exercise. Although the Indian government is working more proactively on the increasing threat of water pollution, it will take far more than political will for these actions to translate into concrete measures resulting in improved water quality. This proves that the third hypothesis is also true.

In the entire research we have examine the impacts of climate change on agriculture, foodgrains production and productivity, rural livelihood, food security, water availability, livestock and fisheries. The climate change has mainly negative effect on these. It is an alarming issue and efforts must be directed towards the minimization of harmful effect of climate change.

5.2 Suggestions

1. Organic farming and sustainable agriculture practices have to be followed without hurting the food security and livelihoods of the population particularly the poor.

2. There is a need to invest in improving agricultural productivity and non-agricultural activities like clean drinking water.

3. The fall in the area under cultivation in Kharif season may be reduced by proper adaptation particularly by choosing those crops in which water requirement is less.

4. Relocation of people and agriculture is one way to adapt to the change in temperature, sea-level and water distribution that might result from climate change.

5. Migration related adaptation would require transfer of human, technological and financial resources from better-off countries and international communities.

6. Detailed studies of crop production data have to be conducted to better estimate the agricultural water use.

7. To sustain the growth in the livestock sector, the challenges like comparatively lower productivity, shortage of feed and fodder and adverse impact on account of climate change need to be addressed.

8. At the international level, new mechanism have to be devised to provide a range of public goods including climate information, forecasting, research and development of crops adapted to new weather patterns, and techniques to reduce land degradation.

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